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SPACE VEHICLE (MISSILE) POWER SUPPLIES
AN ANNOTATED BIBLIOGRAPHY

by

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ABSTRACT

This annotated bibliography contains 700 citations from open literature on power supplies. It is oriented toward batteries, fuel cells, thermionics, thermoelectrics, nuclear energy sources, and other new concepts of direct energy conversion which may be adaptable to space vehicles.

FOREWORD

This bibliography, comprising 700 entries, is the result of a selection of references from indexes, and from an examination of non-classified literature published, chiefly, during the period 1959-July 1967. A few earlier articles are included because of their historical value in considering the development of a body of literature on the subject of power supplies for space vehicles.

As became apparent during the search for material, non-government, open literature (e. g. non-security classified) publications relating to power supplies for missiles, as such, are rather scarce. In addition, therefore, to those articles and books which do mention missiles, specifically, references have been included which appear to contain information applicable to missiles, as well as to other types of space vehicles.

The material selected, as is indicated by the titles and annotations, is concerned with storage batteries, solar cells, fuel cells of various types, nuclear energy, power convertors and inverters, and electronic power supplies, in general. A few references are included which relate to power supplies, chiefly in the form of nuclear energy conversion devices suitable for unattended operation.

Arrangement is alphabetical, by author, with annonymous articles interspersed in their appropriate place, alphabetically, by title entry. A KWIC index, emphasizing the key word in context, facilitates access to the subjects included.

Indexing and abstracting services found useful in the preparation of this bibliography included Direct Energy Conversion Abstracts (formerly Thermoelectricity Abstracts), International Aerospace Abstracts, and Nuclear Science Abstracts.

The periodicals, books, reports and proceedings of conferences referred to should be available from libraries maintaining scientific and technical collections such as the libraries of the American Institute of Aeronautics, libraries of Department of Defense activities, the Library of Congress and the larger public libraries.

Since the cut-off date for collecting material for this report, 99 papers were presented on Advances in Energy Conversion Engineering at the Intersociety Energy Conversion Engineering Conference, held at Miami Beach, Florida, August 11-17, 1967. This conference, led by ASME, presented workshop sessions on: Thermionics, Thermoelectrics, Photovoltaics, Electrochemical Devices, Hydrogen-Oxygen Fuel Cell, Magnetohydrodynamics, and Electrogasdynamics, Nuclear Energy Sources, 0-10 Kw Manned Space Power Applications, 10-50 Kw Space Nuclear Power Applications, Manned Space Power - 50 Kw to Multimegawatts, Unconventional Terrestrial Power, Thermodynamics and New Concepts, and other topics.

CONTENTS

SPACE VEHICLE POWER SUPPLIES

AN ANNOTATED BIBLIOGRAPHY

1. Abrahamson, L. T.
SILVER-ZINC BATTERIES AS SOURCE-PRIMARY ELECTRIC POWER FOR PILOT-LESS AIRCRAFT.
Transactions of the American Institute of Electrical Engineers, 76 (Pt. 2):293-300, Sept. 1957.

General system description and circuit simplification of silver-zinc batteries.

2. Adamson, R. E. L.
WASHINGTON FORESEES MAJOR ROLE FOR NUCLEAR SPACE POWER.
Nucleonics 19:54-57, illus., Apr. 1961.

Nuclear propulsion and auxiliary power are regarded as both inevitable and essential in the exploration and exploitation of space. Some projects are mentioned which lend support to the future possibilities of nuclear-auxiliary power.

3. Agruss, B., Hietbrink, E. H. and Henderson, R. E.
REGENERATIVE FUEL CELLS FOR ENERGY STORAGE.
In Power Sources Conference. Proceedings, 15th, 1961, p. 38-43, figs., Red Bank, N.J., PSC Publications Committee, 1961.

The study indicates basic problems which must be overcome before giving serious consideration to the fuel cell as a workhorse space electrical storage system. Improvement must be achieved in electrochemical characteristics, reduction of polarization losses, providing low resistance reversible cells, and in simplifying the storage system.

4. Allen, J. M.
POWER PLANTS FOR OUTER SPACE.
Battelle Technical Review, 10:3-8, illus., Feb. 1961.

It is indicated that weight factors impose stringent limitations upon energy conversion systems in space vehicles. Systems available or being developed, and their potentialities, are discussed. Energy sources referred to include chemical, atomic, and solar.

5. Altman, M., Chang H. and Ross, D. P.
THE PREDICTION OF TRANSIENT HEAT TRANSFER PERFORMANCE OF THERMAL ENERGY STORAGE DEVICES.
Paper presented at National Heat Transfer Conference, 6th Boston, Mass., Aug. 11-14, 1963.
Chemical Engineering Progress, Symposium Series, 61(57):289-297, 1965.

Study of one aspect of heat of fusion energy storage, the analytical prediction of heat transfer performance. Solar-powered electrical generators depend on some form of energy storage for operation in the dark portion of their duty cycle. Energy can be stored either electrically, as in batteries, or as heat energy, as latent heat of fusion. Thermal energy storage is of importance for two main reasons: it minimizes thermal cycling, and in the case of orbiting space vehicles, savings in weight can occur when thermal energy storage is used, rather than batteries.

6. Angelino, G.
LIQUID-PHASE COMPRESSION GAS TURBINE FOR SPACE POWER APPLICATIONS.
Journal of Spacecraft and Rockets, 4:188-194, Feb. 1967.

A thermodynamic cycle particularly suited for solar power systems is analyzed. It uses hexafluorobenzene as the working fluid. With respect to the general configuration, the cycle is comparable to a highly regenerative Brayton cycle with the exception that a condensation process is present and the compression is performed in the liquid phase. Cycle efficiency and radiator area are computed for the whole probable field of application, and the influence of component efficiencies on over-all performance is investigated. Because of the limited thermal stability of the working fluid, the cycle maximum temperature is below the current space power practice. Notwithstanding this limitation, the cycle characteristics are comparable with those of current space practice and are often superior when compared on an equal maximum-temperature base. A typical efficiency achievable with a maximum temperature of 800°K and a radiator temperature of 80°C is 35%. This compares favorably with the performance of binary Rankine cycles having similar minimum temperature and radiator area.

7. Angrist, S. W.
DIRECT ENERGY CONVERSION.
Boston, Allyn and Bacon, Inc., 1965, 431p.

The history and future of direct energy conversion are examined, and the principles of energy conversion are set forth, including a unified theory of energy converters. A brief introduction to the solid state is given, with particular emphasis on semiconductors. Other topics covered include thermoelectric generators, photovoltaic generators, thermionic generators, MHD power generators, and fuel cells. Other modes of direct energy conversion are also surveyed.

8. Archer, D. H. and others.
WESTINGHOUSE SOLID-ELECTROLYTE FUEL CELL.
In Fuel Cell Systems, p. 332-342, Washington, D. C. American Chemical Society, 1965.

The design and construction of solid-electrolyte fuel cell batteries are discussed.

9. Arifov, U. A., Akramov, Kh. T., Dzhalilov, B. N., Kulagin, A. I. and Makov, N. V.
SOLNECHNYI TERMOGENERATOR S TSILINDRICHESKIM GELIOPRIEMNIKOM (SOLAR THERMOELECTRIC GENERATOR WITH CYCLINDRICAL SOLAR-ENERGY RECEIVER). Geliotekhnika, No. 3, p. 3-6, 1967. In Russian.

Description of a solar thermoelectric generator with an aluminum solar-energy receiver in the form of a 20-face prism with a cylindrical cavity. The generator employed 360 Bi_2Te_3-Bi_2Se_3 and Bi_2Te_3-Sb_2Te_3 alloys as the p- and n- type materials and water-cooled "cold" junctions. Its output power is 35 watts. It is shown that a solar-energy receiver of this type is capable of producing an isothermal surface on the "hot" junctions of the generator.

10. Armour, W. G., Klein, E. A. and Lenhart, D. D.
ELECTRONIC PACKAGING IN THE PHOENIX MISSILE.
IEEE Transactions on Parts, Materials and Packaging, PMP-1: s-237 to s-247, June 1965.

Description of the concepts and techniques used in the electronic packaging of the Phoenix missile electronics unit. The unit consists of etched circuit chassis pairs sandwiched between heat-transfer panels. The sandwiches of heat-transfer panels and chassis are compressed by end plates, and circuits such as logic networks, audio amplifiers, and high-gain dc amplifiers are packaged in unique, welded, plug-in modules; such circuits as i.f. amplifiers and crystal-controlled oscillators are packaged in individual welded modules contained within aluminum investment castings. The other major features described are methods of providing thermal control and structural integrity.

11. Armstrong, J. L.
NUCLEAR MISSILE, ROCKET, AND AUXILIARY POWER PROGRAMS.
In Gantz, K. F. ed. Nuclear Flight, p. 26-34, New York, Duell, Sloane and Pearce, 1959.

Missile and space-oriented programs for developing special applications of nuclear energy are described among them SNAP (System for Nuclear Auxiliary Power) directed toward developing nuclear energy and associated electrical conversion devices into lightweight, long-life power units for space applications. Also in Air University Quarterly Review 11:26-84, Fall-Winter, 1959.

12. ATOMIC GENERATOR FOR SPACECRAFT.
Spaceflight 2:260, Oct 1960.

A brief description of the Snap system is presented including a list of the major components and their functions.

13. ATOMIC POWER FOR SPACE VEHICLES. PROGRESS OF AMERICA'S SNAP PROGRAMME.
Science Horizons 3:3-5, illus., Oct. 1960.

Tells of the development of radio-isotope heated units for power generation.

14. AUTOMATIC SILVER-ZINC BATTERY: INTERNAL CHEMICAL HEATING DEVICE PERMITS INSTANTANEOUS FULL POWER AT LOW TEMPERATURE.
Electromechanical Design 5:22, illus., Jan. 1961.

A silver-zinc battery has been developed that is reported to be the first automatically activated unit to incorporate successfully an internal chemical heating device. The battery needs no preheating from external electrical sources, yet it heats up to full-power temperature several critical minutes faster than conventionally-heated batteries.

15. Azulay, M. and Kirkman, D. W. T.
SOME PRACTICAL APPLICATIONS OF "SEALED" NICKEL CADMIUM BATTERIES WITH CHARGING ARRANGEMENTS ADOPTED FOR VARIOUS OPERATIONAL REGIMES.
Paper Joint Services Electrical Power Sources Committee, International Power Source Symposium, Brighton, Sussex, England, Sept. 20-22, 1966, 10 p.

Consideration of operational aspects of "sealed" Ni-Cd batteries with pocket plates and sintered plates. The "sealed" cell, "sealed" battery life, current reversal, and charging are the topics discussed specifically. Some typical applications of these batteries are described.

16. Badareu, E. Musa, G. and Popescu, D.
INVESTIGATIONS ON THE CAESIUM THERMIONIC CONVERTER WITH AN AUXILIARY DISCHARGE.
British Journal of Applied Physics, 16:845-850, June 1965.

The influence of an auxiliary discharge on the (V, I) characteristic of the caesium thermionic converter has been investigated. The most interesting result appears to be the auxiliary discharge sustained arc mode for relatively low emitter temperatures; under these conditions an auxiliary to output power ratio as low as 6% may be obtained.

17. Barak, M.
DEVELOPMENTS IN ELECTROCHEMICAL ENERGY-CONVERSION DEVICES, BATTERIES AND FUEL CELLS.
Institution of Electrical Engineers, Proceedings, 112:1439-1448, Jly. 1965.

Advances in the development of batteries are discussed and applica-

tions are described. Basic principles and the performance of fuel cells are also discussed.

18. Barber, R. E., Mullaney, J. E. and Bailey, R. N.
PRELIMINARY DESIGN ANALYSIS OF SOLAR-POWERED, LONG DURATION SPACE POWER SYSTEMS FOR A POWER RANGE OF 1 to 25 KW.
American Rocket Society, Space Power Systems Conference., Sept. 25-28, 1962. Santa Monica, Calif., 1962. n. p. (ARS Paper 2569-62).

A generalized weight estimate of the solar concentrator, heat receiver, support and deployment structure, and orientation system is presented for the power range 1 to 25 kw. A weight estimate of the combined power unit and radiator is presented for four example solar energy space power systems over the power range considered. The four example systems are (1) rubidium, Rankine cycle-turbine prime mover; (2) biphenyl, Rankine cycle-turbine prime mover; (3) steam, Rankine cycle-free piston prime mover; and (4) xenon, Brayton cycle-turbine prime mover.

19. Barna, G.
POWER SYSTEMS.
Space/Aeronautics 48:101-106, 1967

Six types of systems are identified as the principal sources of power for long direction missions. Those described, in detail, are photovoltaic solar-energy conversion systems, radioisotype systems with thermoelectric conversion at the higher-power levels, and nuclear reactors with thermoelectric, Rankine=cycle, and thermoionic conversion.

20. Barney, R. A., Kendall, E. G. and Hove, J. E.
AUXILIARY SPACE POWER DEVICES.
In Hove, J. E. and Riley, W. C. eds. Ceramics for Advanced Technologies, p. 338-363, New York, John Wiley and Sons, Inc., 1965.

Secondary, or auxiliary, space power systems are defined as those systems in a space vehicle necessary to furnish power other than that required for direct propulsion. These auxiliary power systems require an energy source which could be solar, nuclear, or chemical. The first group of devices described are those which produce electrical power from sources other than heat, i. e., which are not heat engines. This consists of batteries, fuel cells, solar cells and MHD converters. The next group described is made up of those devices which convert heat into electricity. It includes thermoelectric, thermionic, and mechanical converters. The final group described is made up of isotope and nuclear reactor heat sources, which are the only two (other than the sun) considered feasible for long-time space missions. The thermionic converter using a nuclear-fueled cathode is described in the section on the reactor heat source.

21. Baron, W. R.
THE SILICON SOLAR CELL.
Electronic World 66:33-36, illus., Dec. 1961.

A primary power source for the space age, this device makes possible direct, instanteneous, and efficient conversion of the sun's energy into useful electric power.

22. Bates, J. W.
POWER CONDITIONING SYSTEM DESIGN.
In Wescon/65; Proceedings of the Western Electronic Show and Convention, San Francisco, Calif., August 24-27, 1965, Technical Papers. Part 3 - Power Electronic. North Hollywood, Calif., Western Periodicals Co., 1965, 11 p.

Discussion concerning the optimized power conditioning system and electronic circuitry that will achieve maximum efficiency and reliability, lowest weight, and other performance factors in space-vehicle design. Primary power sources and types of regulators are analyzed, and inverter types as well as centralized and decentralized power-conditioning system designs are investigated. It is concluded that, because energy sources and systems vary from one system to another, it is not possible to lay down a set of rules for power conditioning system design.

23. Baum, V. A.
USE OF SOLAR ENERGY FOR ELECTRICITY PRODUCTION BY DIRECT CONVERSION BY MEANS OF THERMOELECTRIC CONVERTERS AND PHOTO-ELECTRIC CELLS.
United Nations Conference on New Sources of Energy, Rome, June 1961. 31 p., illus.

Three types of converters of solar energy into electricity are discussed (1) thermo-electric, (2) photoelectric and (3) thermionic.

24. Baxter, A. D.
NUCLEAR POWER IN FLIGHT.
Royal Aeronautical Society Journal, 65:565-598, diags., Sept. 1961.

The article is concerned mostly with propulsive power but a paragraph is devoted to modest amounts of auxiliary power provided by thermoelectric conversion.

25. Bean, B. H.
THERMOELECTROSTATIC GENERATOR PROMISES HIGH SPECIFIC POWER.
Space/Aeronautics 35:79-80,82,85-86,88,90, figs., June 1961.

Researchers have found that thermoelectrostatic generators show exceptional promise as power sources for spacecraft propulsion and accessory systems. Such generators, they discovered, could be designed to high specific powers (equivalent to low weight).

A thermoelectrostatic generator essentially is a thin-film capacitor alternately heated by solar radiation and cooled by radiant emission. In this article, the electrostatic and thermodynamic cycles of such a generator are analyzed to show the interaction of the parameters that determine the unit's efficiency. The performance of a hypothetical generator is then summarized on the basis of computer calculations for a system that can realistically be considered feasible. The results prove the thermoelectrostatic generator to be clearly competitive with other forms of chemical and other forms of electric power generation.

26. Becker, R. A.
THERMIONIC SPACE POWER SYSTEMS REVIEW.
Journal of Spacecraft and Rockets, 4:847-851, Jly. 1967.

Survey of the current state of thermionic technology and applications. Three methods for increasing the affinity of thermionic converter electrodes are presented, and one scheme for increasing converter power density is discussed. Three types of heat source needed in conjunction with a thermionic converter for space-power applications are examined. Solar thermionic generators utilize incident solar radiation, which is collected and concentrated by a paraboloidal mirror onto a cluster of thermionic converters. Typical converter outputs in this case are 17 watts/cm^2 with demonstrated life to 13,200 hr and a cumulative test time of 56,000 hr. The second type of heat source, radioisotopes, offers the advantage of efficiency and high heat-rejection temperature. Seven isotopes which could be used in conjunction with thermionic generators are studied. Reactor-heated thermionic systems can be divided into two types: out-of-core nuclear reactor thermionic systems and in-core nuclear reactor systems. Both systems are briefly described.

27. Beller, W.
MAGNETIC FIELD TO SLOW SPACECRAFT.
Missiles & Rockets 8:26-27, Feb. 20, 1961.

Tells of a proposal which would convert heat energy into electric power generating retarding force.

28. Beller, W.
SNAP UNITS WELL ALONG IN DEVELOPMENT.
Missiles & Rockets 7:39-43, Aug. 22, 1960.

Discussion of the uses, design features, and expected performance of the SNAP 2, 8, and 10 nuclear reactor space electric power systems, considering also the relative merits of solar and nuclear electric power sources.

29. Beller, W.
TEN YEARS HENCE HYDRO-CARBON FUEL CELLS MAY POWER TRACKING SITES.
Missiles & Rockets, 12:26,29, Apr. 29, 1963.

Chief advantage of a fuel cell is that its fuel is cheaply obtained easily stored, and shipped. Other advantages fuel cells have over competitors are efficient conversion of fuel to electricity; reliability because of no moving parts; noiseless operation. No electromagnetic signal.

30. Beller, W.
THERMIONIC CELL GENERATES A-C POWER.
Missiles & Rockets, 12:18-19, Feb. 11, 1963.

Ford Instrument device exploits internal pulsing, hence needs no inverters and may be a step to a space solar-thermionic system.

31. Beller, W.
THERMIONIC SYSTEM FOR POWER IN 70'S.
Missiles & Rockets, 11:26-27, Aug. 20, 1962.

A novel thermionic conversion system has shown a new way to achieve highly reliable nuclear-space-power systems in the 300-kw to 1-mw range.

32. Bendersky, J.
ACCESSORY POWER UNITS - PRESENT AND FUTURE.
Hydraulics and Pneumatics 14:94-95, Dec. 1961.

Methods are discussed for providing auxiliary power in space vehicles, and areas in which further development is necessary if future APU requirements are to be met.

33. Berger, C. and Arrance, F. C.
BATTERY POWER SOURCES IN THE TEMPERATURE RANGE 50° - 135°C.
In National Electronics Conference, 20th, Chicago, Ill., October 19-21, 1964, Proceedings. v1. 20, p. 102-106, Chicago, National Electronics Conference, Inc., 1964.

Description of the development of batteries that can be stored and operate at temperatures ranging from ambient to 135°C and higher, for aerospace applications. The following conclusions are reached: (1) laboratory data indicates cycling capabilities of greater than 1500 cycles for silver-zinc, single-cell batteries at 100°C; (2) a new class of separator and electrode materials for batteries has been developed that may give rise to a new, more reliable group of high-energy-density, high-temperature batteries, including the silver-cadmium and nickel-cadmium types; (3) strict temperature control for high-energy-density batteries or complex heat-removal systems are no longer a critical requirement; (4) silver-zinc batteries have been cycled at temperatures as high as 135°C.

34. Bernatowicz, D. T., Guentert, D. C. and Klann, J. L.
SPACE POWERPLANT NEEDS AND SELECTION.
Astronautics and Aerospace Engineering, 1:22-26, May 1963.

Power requirements and factors governing powerplant selection for space application are reviewed.

35. Berry, E. R.
EFFECT OF ELECTRICAL AUGMENTATION ON NUCLEAR ROCKET FLIGHT PERFORMANCE.
ARS Journal 31:92-94, Jan. 1961.

A specific example of the transmission of electrical power from a propulsion reactor to the working fluid is evaluated. Such a scheme increases the specific impulse of a nuclear rocket but imposes a dead weight increase for electrical equipment. In the case studied, thermionic converters produce an arc discharge in the hydrogen working fluid. Arbitrary and approximate assumptions are made, but the effect of them on the results is not considered significant. Other working fluids were considered: Li, LiH, NH_3, and H_2O. It appears that unless heat-to-power conversion equipment lighter than 0.005 lb/ekw can be developed, electrical augmentation offers no advantage.

36. Bicknell, J. E.
REACTORS FOR PROPULSION OF MANNED AIRCRAFT AND MISSILES.
Texas Engineering Experimental Station. Miscellaneous Publication E-72-60: 19-28, Apr. 1960.

The four programs of the Atomic Energy Commission concerned with aerospace application of nuclear energy are discussed. Three are concerned with reactors for propulsion and one is concerned with the application of nuclear energy to generate auxiliary electrical power. Two aeronautically oriented propulsion reactor programs are the manned nuclear-powered aircraft and the nuclear-powered ramjet (project PLUTO). Two space-oriented programs are the nuclear-powered rocket program (Project ROVER) and the nuclear auxiliary power program (Project SNAP).

37. Billet, A. B.
A CRYOGENIC POSITIVE-DISPLACEMENT AUXILIARY POWER UNIT FOR SPACE VEHICLES.
New York, Society of Automotive Engineers, 1964, 8 p. (Paper 921A.)

Brief description of the positive-displacement power system as realized in a hydrogen-oxygen space power internal combustion engine (SPICE). The use of cryogenic hydrogen under pressurized storage that has a high heat capacity permits high thermal efficiency, which is realized by using the fuel stored at a lower temperature as a heat sink and by employing an internal combustion engine to generate high peak cyclic temperatures. This design permits the

cryogenic hydrogen and oxygen to be heated by absorbing heat from the engine heat exchanger and exhaust before it is burned in the combustion chamber. The H_2-O_2 internal combustion engine drives an alternator directly at engine speed. Propellant is supplied to the system either from supercritical tankage or as boil-off gases from propulsion tanks. Possible mission applications are noted to include propulsion and auxiliary power for lunar landing vehicles and Apollo-type spacecraft, an emergency power source for an orbital space station, and a portable power source for tools used in space or on the Moon.

38. Billet, A. B.
RELIABILITY OF HYDRAULIC CONTROLS IN SPACE VEHICLES.
In National Symposium on Reliability and Quality Control, 10th, Washington, D. C., January 7-9, 1964, Proceedings, p. 69-84, New York, Institute of Electronics Engineers, 1964.

Discussion of environmental conditions that will be encountered by future space vehicles and methods for insuring the reliability of hydraulic control systems in outer space. To meet the demanding requirements of future space projects, new design concepts of fluid power control systems are being used, coupled with improved reliability procedures. Some of these concepts include additional redundancy of present design configurations and new auxiliary power concepts such as the hydrogen-oxygen combustion engine.

39. Bills, G. W.
SPACE ELECTRIC POWER TRANSMISSION.
New York, American Institute of Electrical Engineers, [1959?] n.p. (Paper CP-59-861).

The subject of this paper is power transmission exploiting conventional techniques such as power cables. It is determined that space electric power transmission lines will be made of aluminum with a rectangular or ribbon cross section. Direct-current operation of the lines appears to be desirable, especially so when thermoelectric generators for converting nuclear energy to direct-current electricity become available.

40. Bills, G. W.
VOLTAGE AND CURRENT CONTROL FOR SPACECRAFT FUEL-CELL SYSTEMS.
IEEE Transactions on Aerospace, AS-2:478-482, Apr. 1964.

Analysis of a proposed, possible feedback control system for regulating the output voltage and currents of a spacecraft electric power system consisting of parallel fuel-cell modules. Such a control system may be necessary because of the many fuel cell variables that can change the value of the fuel-cell module terminal voltage and cause an unequal division of load between the modules.

41. Bishop, W. B.
ENERGY SOURCE REQUIREMENTS FOR RELIABLE CIRCUITRY.
In National Symposium on Reliability and Quality Control, 11th, Miami Beach, Fla., January 12-14, 1965, Proceedings p. 427-433, New York Institute of Electrical and Electronics Engineers, 1965.

Analysis of circuit reliability when the energy source or "power supply" is included. It is found that such an analysis indicates that small independent energy sources are needed. Several ways of satisfying this need are discussed. An attempt is made to determine (1) the possible advantages of having smaller, more independent, sources of energy for electronic circuits; and (2) the possibility of eventually building such sources. It is concluded that very small sources of energy could be used quite effectively in electronic circuitry design, and that redundancy techniques can be used to overcome the low reliability of such sources. Although more research effort is needed, particularly on small energy sources, it is concluded that the use of small independent sources of energy offers the possibility of improved fabrication techniques for integrated circuitry.

42. Blackmer, R. H. and Phillips, G. A.
ION-EXCHANGE MEMBRANE FUEL CELL COMING FOR SPACE VEHICLES.
Society of Automotive Engineers Journal, 30:82-86, figs., Jan. 1962.

An experimental ion-exchange membrane fuel cell is being developed for use in a wide range of space vehicles. A 9-cell demonstration battery has been constructed using conductively cooled cells.

43. Blair, L. S. amd Ward, J. J.
PARAMETRIC ANALYSIS AND CONCEPTUAL DESIGN OF A RADIOISOTOPE-THERMIONIC SPACE POWER GENERATION SYSTEM.
Paper given at the International Conference on Energetics, Rochester, N. Y., Aug. 18-20, 1965. Preprint. New York, American Society of Mechanical Engineers, [1965] 21p.

The effects on efficient system performance of such design variables as the type of radioisotope used, the diode operating temperatures, the fuel block geometry, and the positioning of diodes around the fuel block are considered. A schematic diagram of the power system, and pertinent equations used in the parametric analysis are included. Results showed that, at lower fuel block power densities, system efficiency maximizes at a fuel block length-to-diameter ratio of 1:1 at high volume power densities, system performance is rather insensitive to length-to-diameter ratio.

44. Blake , F. A.
CALIBRATION OF SOLAR CONCENTRATOR FOR USE IN POWER SYSTEM RESEARCH.
New York, American Rocket Society, 1962, 27 p. (ARS Preprint 2528-62).

Experimental calibration of a rigid solar collector is described. Evaluation of the geometry by optical inspection, of energy collection by calorimeter measurements, and of energy intensity by radiometer tests, is discussed. The effect of necessary accessories on the concentrator performance is presented. These accessories include the tracking system, vacuum-chamber window, and focal-plane mounting hardware. The effects discussed include: determination of collection efficiency as a function of misorientation angle, from 0 to 24 minutes misoriented; transmissivity losses and focused-energy distortion introduced by vacuum-chamber windows; and efficiency as a function of axial position. Flux distribution results, in planes perpendicular to the optical axis and on cylinders around the optical axis, are discussed. Two methods of flux distribution determination are utilized and compared. These are the incremental-energy method using a water calorimeter, and a point-by-point method using a radiometer.

45. Bliaux, J.
PERFORMANCES ACTUELLES ET PERSPECTIVES DE LA CONVERSION THERMOIONIQUE. [PRESENT AND FUTURE PERFORMANCE OF THERMIONIC CONVERSION].
Bulletin d'Informations Scientifiques et Techniques, p. 3-21, May 1966.

Description of research in progress in the Electronic Physics Service at Saclay, France, on the direct conversion of nuclear-produced heat into electricity. The principle and present performances of thermoionic converters are reviewed. The work undertaken at Saclay includes basic and technological laboratory research, and in-pile experiments in the Triton reactor at the Fontenay-aux-Roses Nuclear Research Center. Relatively rapid improvements of the performances and lifetimes of the converters make it appear likely that both space and terrestrial nuclear applications will be found within the next ten years.

46. Block, F. G.
THE DEVELOPMENT STATUS OF THERMIONIC ENERGY CONVERSION IN INDUSTRY.
Society of Automotive Engineers Journal, 71:113, June 1963.

"State-of-the Art" of thermionic energy conversion is briefly covered in this paper. Basic operating principles of thermionic energy conversion are outlined. The problem areas of cesium attack, emitter and collector and converter fabrication techniques are discussed. Application of thermionic converters to solar, nuclear and fossil fuel heat sources is covered. Data on efficiency, power density, weight and life results with various sources are presented.

47. Bolan, P., Cohen, R. and Bordner, G.
AN ENGINEERING EVALUATION OF ADVANCED NUCLEAR THERMIONIC SPACE POWERPLANTS.
New York, American Institute of Aeronautics and Astronautics, [1957] 8p. (Paper 64-766).

Initial study of a 1 Mw(e) in-pile nuclear thermionic space power system indicated a specific weight potential of 2.4 #/Kw. As the preliminary design was refined to include practical converter dimensions, nonuniform emitter temperature effects, nonuniform reactor power distribution, power-conditioning equipment, launch vehicle integration, and detailed component and structure design, the specific weight increased to 25.6 #/Kw.

48. Bolan, P., Cohen, R. and Bentsen, B.
A SOLAR SPACE POWERPLANT WITH LIQUID METAL HEATED THERMIONIC CONVERTERS.
New York, American Institute of Aeronautics and Astronautics, 1964.
12 p. (Paper 64-737).

Presentation of a concept of solar power plants incorporating thermoionic direct energy conversion, which introduces a liquid-metal heat-transfer medium into the system. This fluid carries the solar heat collected in the receiver to the thermionic converters located in the system radiator. Comparisons of the three systems of solar power plants in existence were made on the basis of overall system efficiency, weight, and engineerin g problem areas. A power plant size of 1 kw(e) was investigated using 3000°F as the maximum operating temperature in the direct-heating power-plant concept, and 2500°F in the liquid-metal heated power plant. It is stated that, on the basis of power-plant performance, both thermionic power-plant concepts being considered for on-board power in satellite and space vehicles have about the same overall efficiency averaged over the total orbit with batteries used in the direct heating system, and thermal energy storage in the indirect heating concepts. Solar-cell system efficiencies using batteries for energy storage fall below those of the thermionic systems. It is stated that the indirect system using thermal energy storage is lighter than the other power plants considered, except where battery performance is viewed very optimistically.

49. Bossart, K. J.
AN ENGINEER LOOKS AT SPACE FLIGHT.
Electrical Engineering 79:960-962, Dec. 1960.

A brief description of space flight is presented from the perspective of the engineering disciplines. Brief mention is made of the possibilities of efficient direct energy conversion generators, be they thermoelectric, thermionic, or magnetohydrodynamic. It is indicated that the imaginative electrical engineer is presented with a fertile field.

50. Brandhorst, H. W., Jr.
SOLAR CELLS CALIBRATED ON HIGH-ALTITUDE AIRCRAFT.
Space/Aeronautics, 45:122-123, Jan. 1966.

Description of a method for accurately predicting the power that a

solar cell array will produce in space which is based upon comparative performance measurements in earth sunlight of a given solar panel and monitor cells with a known output under the conditions of outer space. In order for this method to be effective the spectral responses of the monitor cells and the panels must be similar. To calibrate the monitor cells, high-altitutde aircraft can be used, even though these do not fly all the way out of the atmosphere.

51. Brandmaier, H. E. and Kahn, B.
RECENT ADVANCES IN ELECTRO-FLUID DYNAMIC POWER GENERATION.
IEEE International Convention Record, 14(pt. 7): 28-37, 1966.

Brief review of high voltage generating devices and their principles of operation, giving also a description of the more recent advances in direct energy conversion techniques involving electro-fluid dynamic power generation. Theoretical and experimental results are given for a typical supersonic electrogasdynamic generator. The present capabilities and areas for further study are discussed as are the long-range ramifications of the development of practical systems.

52. Breaux, D., Burris, W. L, and Schultz, R. L.
HYDROGEN PROMISING FOR SPACE UNIT SECONDARY POWER.
Society of Automotive Engineers Journal, 69:82-84, illus., Feb. 1961.

Hydrogen characteristics are best suited for integrating power generation with environmental control.

53. Breaux, D. K. and Schultz, R. L.
NON-PROPULSIVE POWER SYSTEMS FOR MISSILES AND SPACE VEHICLES.
Canadian Aeronautical Journal, 6:170-177, May 1960.

Characteristics, applications and state of development are discussed for so-called primary conversion (batteries, cells, reactors, gas generators) and secondary conversion (heat engines, turbines, pumps, engines) methods.

54. Brenan, R. A. and Mason, F. D.
CALCULATION OF OPTIMALLY RELIABLE SOLAR CELL ARRAYS.
Institute of Electrical and Electronics Engineers. Transactions on Component Parts CP-11:367-373, June 1964.

Present state-of-the-art emphasis has been placed on the use of silicon solar cells interconnected in series-parallel groups to form a solar array providing basic power for long lifetime spacecraft (perhaps greater than 3 months). To assure that sufficient power will be available to operate equipments during the specified mission time, a reasonable margin must be designed into an array to compensate the degradation of power output due to catastrophic failures and environmental degradation effects. The degree to which these effects can be compensated becomes a trade-off between weight, cost

and satellite lifetime - the time during which adequate power will be available to operate selected equipments. In this paper, the physics of solar cells, their operation, degradation due to radiation, and particularly random failure events are recounted.

55. Briggs, J. L. and Sirois, L. J.
RADIO-ISOTOPE THERMOELECTRIC GENERATOR.
Institute of Radio Engineers Convention Record 5 (Pt. 9):69-74, 1957.

Recent advances in the field of solid-state physics have greatly enhanced the possibility of developing a practical thermoelectric generator for power supply electronic equipments. The possibility of utilizing an efficient thermopile driven by decay energy derived from isotopes is suggested. The course of development of this device at RADC will encompass three problem areas: (1) geometry and packaging of radio-isotope thermal source; (2) development of efficient thermopile, and (3) consideration of circuits best suited to this type of power supply.

56. Brosens, P. J. and Kitrilakis, S. S.
CESIUM THERMIONIC CONVERTERS AND GENERATORS FOR SOLAR SPACE POWER SYSTEMS.
American Rocket Society Space Power Systems Conference, Sep. 25-28, 1962, Santa Monica, Calif. 1962, 10p. (ARS Paper 2571-62).

The research work on thermionic converters accomplished at Thermo Electron is reviewed. Data obtained for converters, using niobium, tantalum, tungsten, iridium, and rhenium emitters, as a function of interelectrode spacing and converter operating temperatures is given in the form of maximum power density maps. Where extensive data obtained on the performance of a cesium vapor diode thermionic converter are described. Volt-ampere characteristics were obtained for four spacings from 0.002-0.019 in., emitter temperatures in about 50° steps from 1600-2050°K, and cesium pressures to 30 torr. A set of such data for emitters of Nb, Ta, Mo, W, Re and Ir have been obtained. Heat flow through the converter could be measured by an attached calorimeter. A systematic method is described for evaluating the practical significance of this large amount of data to permit the choice of optimum materials and operating points for efficient engineering design. Evidence is presented that the observed saturation current of the extinguished mode represents true temperature-limited emission, and thus may be used to obtain data equivalent to the Langmuir S curves.

57. Brosens, P. J.
SOLAR ENERGY THERMIONIC (SET) CONVERTER.
In Symposium on High Temperature Conversion - Heat to Electricity. University of Arizona, Tucson, Ariz., Feb. 19-21, 1964, p. 294-320. Chicago, Ill., Argonne National Laboratory, 1964.

Over the period May 1961 to November 1963, several designs of thermionic converters were developed by Thermo Electron Engineering Corporation for the JPL Solar Energy Thermionic (SET) program. Some of these have been discussed individually in the literature. This paper aims at presenting an overall view of this design effort and its important results.

58. Brosens, P. J.
SOLAR THERMIONIC GENERATORS FOR SPACE POWER.
New York, American Society of Mechanical Engineers, [1965?] 9p. (Paper 64-WA/SOL-1).

Investigation of the design problem of tailoring the solar space-power systems so as to best use the available solar flux. Since it is difficult to change arbitrarily the size of the system, it is of interest to find the system size which can best fit a variety of missions without the need for alterations which increase the cost and decrease the reliability. An approach to this design problem is presented, and numerical examples are given based on the data obtained from tests on the hardware prototype of a solar thermionic generator.

Article with same title also in American Society of Mechanical Engineers. Series A. Journal of Engineering for Power, 86:281-289, Jly 1965.

59. Brown, E. I. and McJones, R. W.
ENERGY SOURCES FOR MISSILE AUXILIARY POWER SYSTEMS.
Automotive Engineers Journal, 66:82-83, illus., Jly. 1965.

Includes brief discussion of silver-zinc cells.

60. Brown, E. I. and McJones, R. W.
OPTIMIZATION STUDY MISSILE AUXILIARY POWER SYSTEMS (AS VIEWED BY THE EQUIPMENT SUPPLIER) New York, Society of Automotive Engineers, 1958, 12 p., tables.

Considers the various energy sources which may be applied to a self-sufficient APU, the power conversion units necessary to provide the specified form of power output and compares complete system in relation to typical overall requirements.

Also in Soc. Automotive Engineers Journal 66:82-83, Jly. 1965, and Aircraft Engineering 30:236-237, Aug. 1958.

61. Brown, J. M. and Chasteen, J. W.
GROUND SUPPORT EQUIPMENT FOR THE PERSHING WEAPON SYSTEM.
IEEE Transactions on Aerospace and Electronic Systems, Supplement, AES-2:729-745, July 1966.

Description of the ground support equipment developed for the Pershing missile, with a functional description of the missile as well as a general definition of the concept of the Pershing weapon system. Areas specifically covered include: missile transportation, erection, and launching equipment; test, checkout, and firing equipment; and maintenance, communication, and power equipment. For the future, it is expected that improvements will be made in ground support equipment electronics through attention to packaging techniques, systems-integrated design concepts, fault isolation and self-test capabilities, reliability, simplicity through decreased demands on human operators, and reaction time.

62. Brown, K. and Weiser, P.
GROUND SUPPORT SYSTEM FOR MISSILES AND SPACE VEHICLES.
New York, McGraw-Hill Book Co., 1961. 490 p., illus.

Contents: Weapon System Operational Concepts, by K. Brown. Management of Support Systems, by A. R. Anchordoguy. Operational Procedures, by J. W. Tucker. Support Data and the Personnel Subsystem, by T. F. Walton. System Checkout and Launch Control Equipment, by M. C. Peterson. Ground Guidance Systems, by D. E. Lewis. Instrumentation, by W. G. Hodson. Facilities Development, by B. Gale. Launcher Design and Development, by B. M. Willett. Cryogenic Applications, by R. W. Vance. Cryogenic Missile System Hazards, by R. W. Vance. A Fast Reaction Propellant Loading System, by R. B. Hinkley. Weapons Effects, by H. L. Brode. The Survivability of Weapon System Launching Sites, by P. Weiser. Mobility Concept, by D. E. Shonerd. Reliability, by H. R. Powell. Logistics and Maintenance, by E. W. Pickrel.

63. Brun, P. M. and Aronssohn, R.
SOLAR BATTERIES AND THEIR APPLICATIONS.
Electronic Applications, 25:78-88, 1964/1965.

The article deals with the application of silicon photovoltaic cells in solar batteries. After a short description of the general forms of these cells, the mechanism of the operation is discussed, special attention being paid to the efficiency with which luminous energy is converted into electrical energy. Finally, the use of these cells, and in particular their arrangement for application and solar batteries, is dealt with.

64. Brunings, J. E. and Johnson, C. E.
NUCLEAR POWER IN SPACE.
Mechanical Engineering, 89:34-41, Feb. 1967.

Discussion of progress made in the reactor thermoelectric space power program. The 500-watt SNAP 10A has been successfully operated under flight conditions and simulated space vacuum conditions. In this system, hot liquid metal (NaK) carries heat from a reactor to the thermionic converter. The pump is a magnetic device, pulling

the liquid metal. The SNAP 8 system is also described. It can be used for both manned and unmanned applications. For the former, a two-loop configuration provides a nonradioactive secondary loop. The high inherent reliability of thermoelectric power conversion is especially desirable; the flexibility of the plant in terms of power level, lifetime, shutdown and restart capability, configuration. and other attractive features are noted. Specific powers of 25 watts/ft^2 and 4 watts/lb are obtainable.

65. Bucci, N. W. and Briggs, R. W.
ELECTRO-MAGNETIC POWER SYSTEMS FOR SPACE APPLICATIONS.
New York, American Rocket Society, 1961, 8 p. (Technical/Paper 61-188-1882)

Discusses factors affecting the selection and design of an electric generator, its controls, and conversion equipment. It is pointed out that to realize a space power system in the megawatt range which will be a compact and lightweight apparatus will require much research.

66. Bucci, N. W. and Briggs, R. W.
POWER GENERATION AND CONTIONING FOR SNAP.
Nucleonics, 22:51-54, June 1964.

Discussion of current work in the development of electrical machinery and power-conditioning equipment for Rankine-cycle systems employing a liquid-metal coolant. Auxiliary power systems of this type have the following major electrical elements: a rotating electromagnetic generator, means for controlling the generator output voltage, means for automatic system control during startup or abonormal conditions, and switchgear for connecting or disconnecting the generator to its loads. Some of the problems are peculiar to the use of liquid metals as combined lubricants and coolants, involving integration of the generator with the turbine and careful design of the generator itself. Operation of conditioning and control equipment at elevated temperatures is another prime source of difficulty. The impedance introduced by relatively long transmission lines can have a strong effect on system performance and may prove to be a limiting factor in applying 2000-3000-cps frequencies to space power plants.

67. Burns, J. D. and Menetrey, W. R.
SPACE MISSIONS AND AUXILIARY POWER DEMANDS.
Western Aviation, 40:20-23, Oct. 1960.

Chemical, nuclear and solar systems are described and compared. Particular mention is made of photovoltaic systems and solar concentrators.

68. Burns, J. D. and Menetrey, W. R.
SPACE POWER SYSTEMS.
Electromechanical Design 4:30-36, figs., Sept. 1960.

A wide variety of power systems appear theoretically able to provide electrical energy to future space vehicles. The relative advantages of each system in terms of weight and other factors will depend on the success of hardware development program being conducted today. This paper, presented at the 1960 Semi-Annual Meeting and Aviation Conference, ASME, emphasizes the design characteristics and problem areas associated with some important solar power system components.

69. Butcher, C.
SOLAR POWER IN SPACE.
World Aerospace Systems, 2:321,322,324,326, Sept. 1966.

Discussion of the solar cell as the presently most experienced and most reliable energy conversion device for near-earth missions. Its future prospects are examined in conjunction with the possible development of nuclear-thermionic and radioisotope converters. In the Ferranti, Ltd., solar cell design, over 28% of the total of 30% of useful light that may be lost by reflection can be recovered by the use of an antireflective coating and internal power losses are minimized by the selection of a 10 ohm-cm p-type silicon as semiconductor material. Performance is checked under simulated sunlight conditions showing an efficiency of over 10% at 30°C. Current area of Ferranti research is concerned with increasing this performance, which must be achieved to confirm the cell's place in space. It is felt that a significant weight reduction of the solar array assembly will be attained, contributing most to the demanded improvement in overall performance. The use of Ferranti solar cells in UK 1 and ESRO 2 is noted.

70. Butler, C. P., Jenkins, R. J. and Parker, W. J.
ABSORPTANCE, EMITTANCE, AND THERMAL EFFICIENCIES OF SURFACE FOR SOLAR SPACECRAFT POWER.
Solar Energy, 8:2-8, Jan.-Mar. 1964.

An expression for the thermal efficiency of a surface used as a receiver for spacecraft solar-power generation is derived in terms of the solar absorptance, hemispherical emittance, and concentration ratio. Experimental equipment is described in which direct measurements may be made up to 1000°C by using a carbon-arc-image furnace to simulate the sun. Emittance and absorptance data are presented on six polished metals and four plasma flame sprayed coatings from 200 to 800°C. It is shown that thermal conversion efficiencies as high as 40 percent at 800°C can be realized with refractory coatings and with a solar radiation concentration ratio of 50 or 6.9 watts per square centimeter.

71. Campana, R. J. and Roes, J. B.
PRELIMINARY DESIGN AND PERFORMANCE EVALUATION STUDY OF A SOLAR THERMOELECTRIC FLAT PLATE GENERATOR.
In Snyder, N. W. ed. Space Power Systems, p. 187-217, figs., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 4).

The object of the work reported was to study the design and performance of solar power generators to operate in the Venus-to-Mars radial range from the Sun. The design and performance evaluations are based on experimental performance of the thermoelectric elements and their junctions to metallic sheets. Results indicate that thermoelectric conversion of solar energy may be accomplished for 70 lb/ekw by a single generator operating in the Sun-centered radial range from Mars to Venus, 30 lb/ekw in the Earth-to-Venus range and 20 lb/ekw in the Venus region. Means of obtaining electrical power for space vehicle needs are discussed. Advantages over other means of obtaining electrical power for space vehicle needs are described.

72. Campana, R. J.
THE RADIOISOTOPE THERMOELECTRIC GENERATOR.
Electronic Industries, 25:82-85, May 1966.

Description of the design and performance of SNAP-15A, the thermoelectric generator powered by Pu 238. A comparison is made of the efficiency and reliability obtained in the use of semi-conductor or metal thermocouples. Test results, a safety and hazards evaluation, and a description of uses are included.

73. Campbell, J. B. et al.
FOUR ADVANCED POWER GENERATORS POSE HOT MATERIALS PROBLEMS.
Materials in Design Engineering, 51:134-138, June 1960.

The four direct-power generators described are thermoelectric generators, magnetohydrodynamic generators, fuel cells, and thermionic generators. All these generators operate at high temperatures, up to 5000°F in the case of magnetohydrodynamic generators, making the development of new and better materials able to withstand this heat an essential in the near future. The principles of each type of power producer are explained and the properties required for the materials contained in it are enumerated.

74. Caprarola, L. J. and Helwig, W. J.
THERMOELECTRICS FOR SPACE.
In Direct Energy Conversion, p. 13-15. Camden, N.J., Radio Corporation of America, 1963.

Basic concepts of thermoelectric space-vehicle power supplies are presented and the thermoelectric converter which was developed by RCA for the SNAP 10A system is described.

75. Carr, C. H.
WET BATTERIES.
Machine Design, 35:202-211, Apr. 11, 1963.

Discussion of the characteristics of secondary batteries using acid and alkaline electrolytes. The structural features, electrochemical

action, capacity, and applications of various batteries - including the lead-acid, the lead-calcium alloy, the novel "maintenance-free" lead-acid, the nickel-iron, and the nickel-cadmium batteries - are examined in detail. The relative merits and short-comings of these batteries are noted.

76. Carson, W. N. and Hadley, R. L.
AUXILIARY ELECTRODE SPACE CELLS.
New York, American Institute of Aeronautics and Astronautics, [1964?] 7p. (Paper 64-752).

Discussion of the auxiliary electrode concept in sealed cell design, developed to protect the cell against destructive pressure rise during charging. It is stated that this protection is obtained by using the auxiliary electrode to signal the onset of oxygen gas evolution in cells charged at high rates, or by using the electrode to promote gas recombination in the cell at low charging rates. By assuring operation with maximum cell pressures below one atmosphere, the auxiliary electrode permits battery system designs that use a minimum of container or encapsulating material weight; the saving in weight gives a marked increase in the ratio of useful energy in weight for the battery. It is noted that an increase from 5 to 6 watt-h/lb to over 20 watt-h/lb has been found for small silver cadmium space batteries when auxiliary electrodes were used for promotion of gas recombination.

77. Casey, E. F. and Street, G., Jr.
A THERMIONIC POWER SUPPLY USING SOLAR HEAT FOR SPACE APPLICATION.
New York, American Institute of Electrical Engineers, 1959, n.p. (Paper CP59-904m).

Some major problems for satisfactory application are the erection of a solar collector, its orientation in space, and protection against space environmental effects such as imposed by meteorites, zero gravity, and other.

78. Celent, C. M.
UNCONVENTIONAL POWER CONVERTERS.
Electronic Industries, 19:101-116, Sept. 1960.

The development of new methods for generating electricity is discussed. The basic conversion devices studied in this article are magnetohydrodynamic generators, fuel cells, solar cells, nuclear batteries, thermionic and thermoelectric generators.

79. Chapin, D. M.
THE DIRECT CONVERSION OF SOLAR ENERGY TO ELECTRICAL ENERGY.
In Introduction to the Utilization of Solar Energy, p. 153-189. New York, McGraw-Hill, 1963.

Analysis of factors associated with photovoltaic methods for converting solar radiation into electricity. Reviewed are some basic aspects of radiation and properties of semiconductors which make them useful for solar cells. The design and fabrication of silicon solar cells are described, as are the electrical properties of such cells. Techniques involved in putting these cells into practical operation are considered.

80. Cherry, W. R.
THE DEVELOPMENT OF SOLAR CELLS.
Electronic Communicator, 2:9-10, May-June 1967.

Review of the development of silicon solar cells. The construction and characteristics of early solar cells are outlined, and the search, in the late 1950's for materials other than silicon with which to fabricate solar cells is detailed. Studies of the effects of impurities in the silicon crystal and base-region dopants to provide more radiation-resistant properties are discussed, and methods of fabricating these devices are described.

81. Cherry, W. R.
SOLAR ENERGY SYSTEMS FOR SPACE APPLICATION.
In Power Sources Conference Proceedings, 17th, 1963, p. 12-15. Red Bank, N. J., PSC Publications Committtee, 1963.

This paper discussed factors affecting design of solar cell systems, solar array types, properties of solar cell systems, hazards in space on solar cell arrays, and future outlook and aims for solar power.

82. Cherry, W. R. and Zoutendyk, J. A.
THE STATE OF THE ART IN SOLAR CELL ARRAYS FOR SPACE ELECTRICAL POWER.
New York, American Institute of Aeronautics and Astronautics [1964?] 39p. (Paper 64-738).

Review of the advances experienced in solar-cells, since the original use of solar cells for electrical power generation in space. The solar cell itself has been improved in many ways. The methods used to connect cells into modules as a building block for constructing large arrays have also been improved. New methods in the soldering of cells into modules have decreased the degradation of the cells due to handling and soldering. In addition, the successful fabrication of cells into modules has made possible the matching of cells by modules, rather than by single cells. It is stated that the methods used to mount the modules to the supporting structure have been improved by using better techniques and bonding agents. With these advances, Sun-oriented arrays have been built with output which approach 10 watts/ft^2 and 10 watts/lb when operated in near-earth space (with no particle radiation damage).

83. Cherry, W. R.
STATUS OF PHOTOVOLTAIC SOLAR ENERGY CONVERTERS.
IEEE Transactions on Aerospace and Electronic Systems, AES-1:10-19, Aug. 1965.

Discussion of the current technology in solar cells, their models and mounting and the improvements needed, with an estimate of the future for these devices. Solar cells are expected to dominate the spacecraft power generation field into the 1970s. Power requirements are reported as having increased from the few hundred milli-watts of Vanguard I to the 1 kw of the Orbiting Astronomical Observatory.

84. Chesner, R. J. and Prestridge, J. C.
CAPILLARY FUEL CELL ORBITAL EXPERIMENT.
New York, American Society of Mechanical Engineers, 1965. 9p. (Paper 65-AV).

Description of the design, development, and testing of a space-oriented, hydrogen-oxygen, capillary, fuel-cell system.

85. Clark, E.
MAJOR ROLE PLANNED FOR SNAP-TYPE UNITS.
Aviation Week and Space Technology, 72:26-27, Apr. 1960.

Nuclear-electronic power system, typified by NASA's SNAP-8, are expected to become the predominant and most reliable sources of propulsive and secondary power for satellites and space probes in the 1965-1970 period.

86. Cochran, D. L., Biehl, A. T. et al.
NUCLEAR AUXILIARY POWER FOR SPACE VEHICLES.
Society of Automotive Engineers Journal, 8:64-67, Aug. 1959.

The three main problems of a space nuclear APU are its radiator, energy conversion cycle and materials.

87. Cochran, J. S., Bloom, J. L. and Schneider, A.
PRODUCTION OF STRONTIUM-90 THERMAL POWER SOURCES.
In Industrial Uses of Large Radiation Sources. 2:157-172. Vienna, International Atomic Energy Agency, 1963.

One of the most attractive fields for utilization of large quantities of waste fission products is the field of direct-conversion power supplies for remote locations. Sr^{90} is being given the greatest exploitation because of its availability, nuclear properties, and the relative ease with which it can be fabricated into compact heat sources. Sr^{90}-fueled generators are being used to power automatic weather stations and navigational aids, and consideration is being given to the use of Sr^{90} as a power source for space vehicles. Evaluation of several potentially useful strontium compounds led to the selection of the titanate as exhibiting overall properties most desirable for this purpose.

88. Cohn, E. M.
FUEL CELLS, PROGRESS PROGRAMS, AND PROBLEMS.
Fusees et Recherche Aeronautique, 18:31-32, 1962.

A large part of the interest in fuel cells that has been shown in recent years has resulted from their potentialities as power sources for space vehicles. Although estimates vary, it is generally agreed that fuel cells, with power outputs ranging up to kilowatts or even megawatts and operating either as primary or secondary power sources, will have a place in the space program, once their feasibility and reliability have been established.

89. Cohn, E. M.
THE GROWTH OF FUEL CELL SYSTEMS.
In Engineering Developments in Energy Conversion; International Conference on Energetics, University of Rochester, Rochester, N. Y., August 18-20, 1965, Proceedings p. 252-265, New York, American Society of Mechanical Engineers, 1965.

Description and evaluation of fuel cell systems for converting the chemical energy of fuels directly into electrical energy. A fuel cell is a chemical reactor having a positive and a negative electrode separated by an electrolyte and externally connected to a load. The main difference between such a cell and a conventional galvanic cell is that the fuel cell does not contain the reacting materials and the electrodes remain unchanged. Systems requirements are discussed. The problems of optimizing a power system for space and more specifically hydrogen-oxygen fuel cells are analyzed. The details of the Gemini solid polymer ion-exchange membrane fuel cells are described. The Apollo system, which is a modification of the Bacon fuel cell, is discussed and it is shown that the modified Bacon cell has the highest efficiency of any known H_2-O_2 cell. The asbestos fuel cell system is considered.

90. Cohn, E. M.
TERRESTRIAL APPLICATIONS OF ELECTROCHEMICAL SPACE POWER RESEARCH.
New York, American Institute of Mechanical Engineers, [1966] 6 p.(Paper 66-1012).

Description of new and improved electrochemical power components that meet the extreme requirements of space applications and that are used in the commercial market. A new concept of battery packaging, improved battery separators, secondary batteries that function for five years without maintenance; space-type fuel cells incorporated into a low-power, long-lived, self-contained power source, are some examples of electrochemical power sources for space that benefit the consumer.

91. Colbeck, D. B.
LOW RATE SEALED ZINC-SILVER OXIDE BATTERIES.
In Power Sources Conference, Proceedings, 17th, 1963, p. 135-138. Red Bank, N. J., PSC Publications Committee, 1963.

Design and fabrication of sealed silver-oxide-zinc batteries for space applications are discussed.

92. Coleman, J. H.
ISOTOPE DEVICES PRODUCING ELECTRICAL ENERGY.
In Seminar on Advanced Energy Sources, 1958, Proceedings, p. 158-164, Fort Monmouth, N. J., 1959?

Principles of operation of existing isotope power sources are described and this background used to suggest isotope generator structures for outer space.

93. Coleman, J. H.
NUCLEAR ENERGY SOURCES.
In Battery Research Conference. Proceedings, 12th, p. 108-110, Fort Monmouth, N. J., U.S. Army Signal Research & Development Laboratory, Power Sources Division, 1958.

Describes the significant features of microwatt, direct conversion nuclear batteries and proposes a kilowatt nuclear battery for outer space applications without the temperature limitations of the systems involving chemical or solid state reactions.

94. Comer, J. E.
CRITICAL COMPONENT PARTS IN SPACE POWER EQUIPMENT.
Evaluation Engineering, 5:6-7, May-June 1966.

Review of the reliability testing and performance of semiconductor devices, in which peak power is identified as the most overlooked feature in stress analysis. Peak-power failures occur in power-handling transistors under such conditions as turn-on, short circuit, or during switching under heavy loads. The methods of analyzing peak-power stresses in component parts used in power equipment are discussed. The worst-case conditions for peak-power measurements are not always analyzed due to their intermittent or singular nature, but repeatable conditions requiring special attention during testing are identified, including overlooking high transient voltage conditions, which may cause failure in the input circuit, and exceeding the dv/dt limits of small silicon-controlled rectifiers, causing inadvertent turn-on of the device.

95. Comer, J. E.
TRENDS IN RELIABILITY OF SPACE POWER CONDITIONING EQUIPMENT.
In Wescon/65; Proceedings of the Western Electronic Show and Convention, San Francisco, California, August 24-27, 1965, Technical Papers. Part 3 - Power Electronic. North Hollywood, California, Western Periodicals Co., 1965. 5 p.

Review of the organization, stress analysis, component part specifi-

cations, and failure of space power conditioning equipment. It is concluded that major potential failure mechanisms can be avoided by timely reliability design and stress reviews, and that for many semiconductors peak power measurements are more important than average power.

96. Contzen, J. P.
CRITERES DE SELECTION DES RADIO-ISOTOPES A USAGE SPATIAL [CRITERIA FOR THE SELECTION OF RADIOISOTOPES FOR SPACE USE.]
Revue Technique CECLES, 1:245-273, Oct-Dec. 1966.

Description of the possible uses of radioisotopes in space and discussion of the criteria to be used in selecting the most appropriate radioelements for these applications. On the basis of these criteria, a list is given of those isotopes which are currently the most suitable for propulsion and for auxiliary power generation.

97. Contzen, J. P.
PROSPECTS OF USING RADIOISOTOPES IN SPACE.
Industrial Applications for Isotopic Power Generators, p. 43-54, Paris, European Nuclear Energy Agency, 1967.

The uses of radioisotopes in space are identified. Attention is concentrated on the two major categories of application: propulsion and electric power generation. A tentative selection of the most suitable isotopes is made for both types of system, and problems which arise from their development are analyzed. Utilization prospects are projected from this analysis, particularly from a European point of view.

98. Cook, N. A.
HYDROGEN OXYGEN FUEL CELL SYSTEM DESIGN PARAMETERS.
In Energy Conversion and Storage; Proceedings of the Annual Conference, 3rd, Oklahoma State University, Stillwater, Oklahoma, October 28, 29, 1965, p. 2-1 to 2-14. Stillwater, Oklahoma, Engineering and Industrial Extension of Oklahoma State University, 1965.

Consideration of the system concept of fuel cells, in general, and of the design and construction of a particular H_2-O_2 fuel cell system. The four physical phenomena associated with a fuel cell are discussed: the electrochemical oxidation with the resultant production of useful electric energy; transfer of ions through an electrolyte; water production within the cell; and thermal energy generation within the cell. Cell types are examined, including the wick, free electrolyte, and circulating-gas types. Schematics are presented of the circulating moisture removal electrolyte system and fuel cell auxiliaries and control. System operation with respect to safety and hardware is considered. For purposes of comparison, a summary in tabular form of all basic data concerning the H_2-O_2 fuel cell system is given.

99. "COOL" METHOD OF MHD GENERATION MAY MAKE IT PRACTICAL FOR SPACE FLIGHT. Electrical Engineering, 81:806-807, Oct. 1962.

A "cool" method for ionizing gases in a magnetohydrodynamic (MHD) generator which could lead to the practical use of this new electric power generation process with nuclear reactors has been discovered.

100. Cooley, W. C.
SOLAR DIRECT-CONVERSION POWER SYSTEMS.
Institute of Radio Engineers Transactions, MIL-6:91-98, illus., Jan. 1962.

A survey is made of the status of technology of solar photovoltaic, photo-emissive, thermoelectric and thermionic power systems for spacecraft. The subjects of radiation damage to solar cells, power-system design, and solar simulation are reviewed. Various types of solar power systems are discussed and compared with respect to weight, availability, environmental tolerance, and cost. It is concluded that solar photovoltaic and solar thermionic systems are most desirable for power levels up to 3 kw. However, the life capability of thermionic converters has not yet been established. Solar thermoelectric and photoemissive systems will be less desirable because of their lower efficiency and, therefore, larger area per unit power output, except for missions where radiation resistance or economy are paramount considerations.

101. Coombs, M. G. and Norman, L.
APPLICATION OF THE BRAYTON CYCLE TO NUCLEAR ELECTRIC SPACE POWER SYSTEMS.
New York, American Institute of Aeronautics and Astronautics [1964] 24 p. (Paper 64-757).

Review of the status of the studies and experiments conducted by AiResearch Manufacturing Company on Brayton closed-cycle space power systems as applicable to nuclear-power heat sources. The two nuclear heat sources are the radioisotope and the nuclear reactor. A summary is shown of specific weight and specific area data that have been generated by AiResearch for Brayton-cycle power systems employing nuclear reactors as the heat source. It is concluded that significant progress has been made in the development and demonstration of recuperative Brayton-cycle power system components and system concepts. Earlier theoretical estimates of component performance have been experimentally verified, and most of the results have exceeded the conservative predictions made for these components. As a result, the estimates of size, weight, and performance of Brayton-cycle space power systems are on a more defensible basis than they were sometime ago.

102. Cooper, D. W. and Kuhns, P. W.
ELECTRICAL GENERATOR WITH A SUPERCONDUCTING MAGNETIC FIELD FOR USE IN A 1-MEGAWATT ROTATING SPACE POWER SYSTEM.

In Intersociety Energy Conversion Engineering Conference, Los Angeles, California, September 26-28, 1966, Technical Papers, p. 298-307. New York, American Institute of Aeronautics and Astronautics, 1966.

Analysis of a space turboelectric generation system delivering 5000 vdc at a 1-Mw power level. This system employs a superconducting field as the stator with a 200 to 340°K rotor as the armature. Both ac and dc models of this generator are studied for possible spacecraft use. The final electrical output power is taken as 5000 vdc, as would be necessary in an electropropulsion mission. A comparison with other rotating generation systems that might be used as alternatives shows that the superconducting-magnet generator system holds promise of being lighter in weight and more efficient. Consideration is also given to the effects of refrigeration system weight and to the seal, bearing, and electric-contact problems in space.

103. Cooper, J. E. and Ingling, W.
SEALED ALKALINE BATTERIES FOR SPACE APPLICATIONS.
Institute of Electrical and Electronics Engineers. Transactions, AS-1: 34-37, Feb. 1963.

The purpose of this paper is to consider the capabilities and major limitations of the nickel-cadmium, silver-cadmium, and silver-zinc alkaline secondary battery systems. The considerations of each of these systems are based on analysis and development work currently underway. The primary mode of operation considered is an orbital or charge-discharge type cycling at various temperature and depths of discharge. A brief failure analysis resume' is also presented.

104. Corliss, W. R.
NUCLEAR POWER IN OUTER SPACE.
Nucleonics 18:58-63, Aug. 1960.

Space missions will need power sources in a variety of sizes. Existing radioisotope sources can furnish watts of power; compact reactors now under design will provide megawatts.

105. Corliss, W. R.
PARAMETERS FOR RADIOISOTOPE GENERATOR DESIGN.
Institute of Electrical and Electronics Engineers; Special Publication, S-145:152-163, Feb. 1963.

General characteristics are discussed of radioisotope generators that fill many needs for space power requirements in range from 0.1 to 500 electric watts.

106. Corliss, W. R. and Harvey, D. G.
RADIOISOTOPIC POWER GENERATION.
Prentice-Hall International Series in Space Technology. Englewood Cliffs, N. J., Prentice-Hall, Inc., 1964, 312p.

A survey is presented of general design considerations (radioisotope fuels, safety, energy conversion characteristics, and generator design principles) and specific radioisotope generators (space units, nuclear batteries, and advanced concepts).

107. Cox, A. L.
COLLOIDAL ELECTROHYDRODYNAMIC ENERGY CONVERTER.
New York, American Rocket Society, 1962, 10p. (ARS Preprint No. 2559-62.)

The colloidal electrohydrodynamic energy converter described changes the thermal energy of a slightly ionized superheated vapor to directed kinetic energy, then to high-voltage electric energy. High conversion efficiency is possible if neutral atoms can be made to condense on the ions, which are being pushed against a retarding electric field. Radiation and radiator requirements of the system are noted. The electric power output attainable should be better than 0.4 kw/lb at 500 kw. Use of the system for propulsion and internal power for spacecraft is discussed. Performance of Hg, K, Na, and Li as working fluids is described.

108. Cox, D. W.
SPACEPOWER: WHAT IT MEANS TO YOU.
Philadelphia, Winston, 1958, 262 p.

A solar power mirror on a space probe which is utilized to send telemetered messages to earth is mentioned (p. 111) and shown in a diagram (p. 110). The employment of nuclear power in spacecraft is described on pages 128-134.

109. Crane, W. E., Robinson, R. L. and Roessler, W. U.
HIGH POWER AND ENDURANCE PRIME NEEDS FOR SPACECRAFT AUXILIARIES.
Society of Automotive Engineers Journal, 72:63-69, Aug. 1964.

This article discusses the states of development and predicted capabilities of devices that may meet future needs for high power and endurance spacecraft nonpropulsive power systems.

110. Crane, W. W. T.
SPACE POWER.
In International Astronautical Congress, London, 1959. Proceedings, 2:748-755, illus., Wien, Springer Verlag, 1960.

Recent research and test data are described which indicate so far that a safe, reliable and practical radioisotope-fueled auxiliary power supply can be built using existing technology.

111. Crawford, J. J.
SILVER ZINC SECONDARY BATTERY RELIABILITY.
In 1967 Annual Symposium on Reliability, Washington, D. C., January 10-12, 1967. Proceedings, p. 323-328, New York, Institute of Electrical and Electronics Engineers, Inc., 1967.

Description of models for the silver-zinc secondary cell and battery. These models will enable the user of such systems to evaluate the reliability of a battery in a given application. It is pointed out that the work performed should lead to further refinements of the cell modeling and additional considerations in the evaluation of cell data for these calculations. It is hoped that the resulting efforts will provide both a firmer basis for battery knowledge and also predictability with regard to useful performance.

112. Crompton, C. E.
ISOTOPIC POWER.
Industrial Research, 3:78-83, Oct., 1961.

The use of isotopic-powered generators for the TRANSIT and SNAP project is discussed, and evaluation of radio-isotope-fueled power sources is presented, and future space applications are outlined.

113. Curran, R. W.
NON-PROPULSIVE POWER FOR ADVANCED VEHICLES.
Space Aeronautics, 33:42-44, Mar., 50-53, Apr., 52-54, May 1960.

Part I gives analysis of factors that determine selection of non-propulsive power systems for manned and unmanned extra-atmospheric vehicles. Shows typical profiles for a variety of space missions and reviews pros and cons of different power systems. Part II gives analysis of advantages, disadvantages, application areas, and growth prospects for battery; solid-fueled; liquid-fueled mono- and bipropellant open cycle, expansion-engine; and chemically fueled closed-cycle thermomechanical power systems. Part III reviews fuel cell, solar and nuclear designs for power sources of a space vehicle.

114. Cusano, D. A.
THE PERFORMANCE OF THIN FILM SOLAR CELLS EMPLOYING PHOTOVOLTAIC Cu_{2-x} Te-CdTe HETEROJUNCTIONS.
Paper Presented at Colloque International sur les Photopiles Solaires en Couches Minces, Universite d'Aix-Marseilles, Marseilles, France, May 19, 20, 1966. Revue de Physique Appliquee, 1:195-200, Sept. 1966.

The paper is a short status report on the continuing development of Cu_{2-x}Te-CdTe thin film solar cells for eventual aerospace application. The fabrication and operating characteristics are described, as well as on-earth maintenance, stability to thermal cycling, and resistance to radiation. Experiments with single crystal junctions are used to obtain a basic understanding of the Cu_{2-x}Te-CdTe junctions, and to guide future thin film work. The most pressing current need is to determine how to extend cell life, particularly at elevated temperatures.

115. Dalcher, A. W. and Sutherland, J. D.
DESIGN OF THE SNAP 10A REACTOR.
New York, American Society of Mechanical Engineers, 1964. 8p. (Paper 861D).

Description of the reactor component of the SNAP-10A (Systems for Nuclear Auxiliary Power) nuclear power unit designed to provide a minimum of 500 watts electrical power at 28.5 volts dc for a period of 1 yr in a space environment. The SNAP-10A reactor is a high-temperature, liquid-metal-cooled reactor designed for satellite and other space applications. The reactor structure is designed to withstand a multitude of environmental conditions, including launch and operational loads, space vacuum, meteoroids, high temperature, nuclear irradiation, and liquid metal corrosion. Other design considerations are fabricability, and nuclear, thermal, and mechanical compatibility with the rest of the SNAP-10A system. The validity of the reactor design is verified by a series of nuclear and environmental tests on both a component and system basis.

116. Dalfonso, J. L.
LA MINIATURISATION ET LA PILE ELECTRIQUE [MINIATURIZATION AND THE DRY CELL].
Technique et Science Aeronautiques et Spatiales, p. 455-460, Jly-Aug. 1966. In French.

Discussion of nonrechargeable batteries for miniaturized components. The "simple" cell (two metals, dissimilar in the electro-chemical series, immersed in a electrolyte) and the electro-chemical series are briefly described. Attention is given to alkaline and mercury cells, with comments on other types.

117. Dalin, G. A., Sulkes, M. and Stachurski, Z.
SEALED SILVER-ZINC BATTERIES.
In Power Sources Conference Proceedings, 18th May 19-21, 1964, p. 54-58. Red Bank, N. J., PSC Publications Committee, 1964.

The principal objective of this program is the development of silver-zinc batteries which can function sealed over a wide range of conditions.

118. d'Amelio, C.
STUDIO DI UN CICLO TERMICO PER MACCHINA SOLARE SPAZIALE [STUDY OF A THERMAL CYCLE FOR A SOLAR ENGINE IN SPACE]
Missili, 6:21-28, Feb. 1964. In Italian.

Proposed space application of a saturated-liquid thermal cycle for energy conversion. The efficiency and useful energy output as a function of Θ and Θ_m, respectively, equal to T/T_{min} and $T_{max}/-T_{min}$, are compared with those for the Rankine and ideal Carnot cycles. It is claimed that application of the proposed cycle would permit a 20% reduction in the weight-power ratio of existing solar plants.

119. Daniel, A. F.
ELECTROCHEMICAL CONVERSION OF ENERGY.
In Conference on Space Technology, Dallas, Tex., April 11-13, 1960, Papers. Electrical Engineering in Space Technology, p. 41-45, New York, American Institute of Electrical Engineers, Dec. 1960.

Characteristics of electrochemical systems of importance to space applications are considered. They are: dry primary batteries, wet primary batteries, storage batteries, molten electrolyte batteries or thermal batteries, primary fuel cell batteries, and regenerative fuel cell batteries.

120. Daniel'-Bek, V. S.
METODY RASCHETA UDEL'NOI ENERGII TOPLIVNYKH ELEMENTOV [METHODS FOR CALCULATING THE SPECIFIC ENERGY OF FUEL CELLS].
Inzhenerno-Fizicheskii Zhurnal, 6:85-87, Dec. 1963. In Russian.

Discussion of the conditions necessary to obtain maximum specific energy of a power source composed of a fuel cell (battery) and a supply of active materials. Two expressions for calculating maximum specific energy are derived, as are expressions which are valid for the case where part of energy is required to generate the active materials.

121. Daniels, F.
DIRECT USE OF THE SUN'S ENERGY.
New Haven, Conn., Yale University Press, 1964, 374p.

Among the uses of solar radiation discussed in this book are: thermoelectric and thermionic conversion, photovoltaic conversion, photochemical conversion and storage and transportation of power.

122. Darland, W. G., Jr.
ECCENTRIC SEPARATOR FOR GALVANIC BATTERY.
U.S. Patent 3,156,588, October 27, 1961, (to the United States of America as represented by the Secretary of the Navy).

In a galvanic battery for use as a power source in a spinning projectil the battery having a plurality of chemically coated annular plates surrounding a frangible electrolyte containing ampule, the ampule being frictionally supported above a breaker platform, the plates and the ampule incapsulated in a molding compound in a manner to form an ampule cavity and a fill channel, a thin annular separator interposed between each pair of plates to form a plurality of cells, each of the separators comprising an outer annular portion, an inner annular portio a web connecting said outer annular and inner annular portions over a small area, said inner annular and outer annular portions being radially spaced in a manner to form an eccentric channel therebetween, said inner annular portion having an annular opening therein surrounding said ampule and an entry-port there-through diametrically opposite said web whereby when the projectile is fired, the ampule is

broken against the breaker platform to release the electrolyte and the cells formed by said separators and the plates are filled with electrolyte the spin of the projectile to activate the battery. (U.S. Patent Off.Off.Gas., 808:578, Nov. 10, 1964.

123. Daussat, P. L.
LES CELLULES SOLAIRES - LEURS UTILISATIONS SPATIALES ET TERRESTRES [SOLAR CELLS - THEIR TERRESTRIAL AND SPACE USES]
Forces Aeriennes Francaises, p. 727-742, Dec. 1964. In French.

Review of research and developmental work by the French Electronic and Applied Physics Laboratories (LEP) and others to determine the practicability of direct transformation of solar energy into electrical energy by utilization of the photovoltaic effect on a semiconducting body. Experiments have been undertaken in collaboration with the University of Chile in the Chilean desert zone which are considered to have shown the excellent resistance of solar cells to atmospheric agents. Principles of operation and the photovoltaic effect on silicon and germanium junction diodes are discussed, and the electrical characteristics of solar cells are described. The industrial production of such cells in France could be undertaken, it is considered, using silicon as the principal material, and using procedures already developed. For space uses, solar cells should be rectangular rather than circular to permit batteries of them to be most effectively placed on panels, although this entails higher costs.

124. Davis, J. I.
SOLAR CELL R AND D.
Space/Aeronautics, 31:44-46, illus., Apr. 1959.

Next target for solar cell engineers is the two-kilowatt power supply that has been proposed for space vehicles. To reach it, higher efficiencies must be achieved in the designs based on the present state of the art.

125. Daye, C. J.
THE SUNFLOWER SYSTEM - SOLAR POWER FOR SPACE.
Mechanical Engineering, 83:56-59, Dec. 1961.

The design, operation, turbine-alternator package and growth potential of the Sun-flower I solar power converter system are explained in detail.

126. Del Duca, M. G., Fuscoe, J. M. and Johnston, T. A.
FUEL CELLS FOR SPACE VEHICLES.
Astronautics 5:36-44, Mar. 1960.

The closed-cycle regenerative fuel cell which has potential as a long-running, high-efficiency power source for space applications is discussed.

127. Del Duca, M. G., Fuscoe, J. M, and Johnston, T. A.
REGENERATIVE FUEL CELLS AS AUXILIARY SUPPLIES FOR SPACE VEHICLES.
New York, American Rocket Society, 1959, n.p.(ARS Paper 1039-59.)

Special requirements of auxiliary power units for space applications such as start-up, radiators, shielding the effects of space environment, etc., are considered. A detailed analysis of a nuclear regenerative fuel cell system using lithium and hydrogen as fuels with a power output of 550 watts at 28 volts is presented along with a discussion of the optimization procedure utilized in the derivation of the conceptual design. Peformance parameters of selected systems are itemized.

128. Demler, M. C.
ELECTRIC POWER FOR FUTURE FLIGHT VEHICLES.
Electrical Engineering, 77:997-999, Nov. 1958.

The era of the space age presents a tremendous challenge to the electrical engineering profession. Electric power is essential not only in the launching of satellites or space vehicles, but also in providing the energy for instrumentation and habitation, as well as propulsive power.

129. Denington, R. J. and Moss, T. A.
NUCLEAR POWER SUPPLIES.
Space/Aeronautics, 44:115-118, 1965.

Review of the characteristics of nuclear power sources for use on board spacecraft. The properties of a number of radioisotopes of primary interest for space power generation are described.

130. Desvignes, F.
VELLULES SOLAIRES PHOTOVOLTAIQUES: NOUVEAUX RESULTATS THEORIQUES ET EXPERIMENTAUX [PHOTOVOLTAIC SOLAR CELLS: NEW THEORETICAL AND EXPERIMENTAL RESULTS].
In Space Radio Communication, p. 240-256, New York, Elsevier Publishing Co., 1962.

Analysis of the energy conversion in solar cells, from the incident light to power consumed in the external load. The process is split into three independent phases: (1) energy transfer from photons to hole-electron pairs; (2) photoelectric minority carrier collection at the depletion layer; and (3) energy transfer from the collected minority carriers to the external load. In addition, the most important properties of silicon cells are reviewed from the viewpoint of space communications applications.

131. Devin, B., Bliaux, J. and Lesueur, R.
DIRECT CONVERSION OF HEAT INTO ELECTRICITY IN REACTORS.
Journal of Applied Chemistry, 15:i-547, June 1965.

French developments in the conversion of heat into electricity by integration of thermionic diodes inside a nuclear reactor to obtain a min.-wt., quasi-permanent source of high energy for use in spacecraft or power installations are reviewed.

132. Dieckamp, H. M., Balent, R. and Wetch, J. R.
COMPACT REACTORS FOR SPACE POWER.
Nucleonics 19:73-76, illus., Apr. 1961.

SNAP reactors using thermoelectric and thermionic converters are described.

133. Dieckamp, H. M., Balent, R. and Wetch, J. R.
REACTOR DIRECT-CONVERSION UNITS.
[Geneva Switzerland, United Nations, 1964], 13p. (Paper 28/P/218).

Description of the SNAP-10A 500-watt auxiliary power unit employing thermoelectric power conversion. The reactor concept chosen for the SNAP 10A to provide the lightest weight high-temperature reactor is homogeneous, U^{235}-fueled, zirconium-hydride moderated, Be-reflected, reflector-controlled, and liquid-metal cooled. Tests with preliminary test reactors are reviewed, and the design of the specific reactor for SNAP 10A is discussed. The effect of the space environment conditions on the design considerations for the thermoelectric power conversion system is described, and the integration of the reactor heat source with the power conversion system is discussed. Safety considerations and the expected performance characteristics for the system are outlined.

134. Dieckamp, H. M.
THE SNAP 2 CONCEPT.
New York, American Rocket Society, 1960, 11p. (Paper 1324-60).

The objectives of the SNAP 2 program are to develop, test, and qualify a 3 Kwe nuclear auxiliary power unit for space utilization prior to 1964. The overall SNAP 2 development effort is directed toward these general objectives: minimum weight, maximum reliability, operational safety, producibility, mission environment compatibility, and minimum payload design restrictions.

Also in Snyder, N. W. ed., Space Power Systems, p. 271-279, New York, Academic Press, 1961.

135. DIRECT-CONVERSION PROJECTS FOR SPACE IN THE SOVIET UNION.
Nucleonics, 22:74-75, Oct. 1964.

The Russians report results of work with thermionic reactors and isotope thermoelectric sources in an official release of detailed information on energy conversion and nuclear power-source projects.

136. DIRECT ENERGY CONVERSION TRAVELS THE PATHWAYS OF TOMORROW.
Signal, 18:49, Aug. 1964.

A panel discussion at the 18th AFCEA Convention evaluates the state-of-the-art in each of three direct energy conversion techniques. The three methods are solar cells, thermoelectric converters and thermionic energy converters.

137. Dittmann, J. F.
THE CAPABILITY OF THE CADMIUM-SILVER OXIDE SYSTEM.
Santa Monica, Calif., [American Rocket Society], 1962, 6p. (ARS Paper 2564-62).

Investigative studies conducted on the cadmium-silver oxide system have demonstrated the feasibility of operating both sealed and vented batteries at the two capacity levels of the positive plate. Operation of a sealed cell at its maximum positive plate capacity over a period of long cycle life is presently limited by the inability of maintaining the silver dioxide level without experiencing excessive internal pressures at practical charging rates. Operating the sealed cadmium-silver oxide cell at the lower capacity level of the positive plate offers several important advantages in achieving extremely long cycle life. However, it is realized that to attain long cycle life by this method, a sacrifice must be made in energy outpout per unit weight and volume. By subjecting sealed cells to various conditions of cycling, it has been demonstrated that the cadmium-silver oxide system has a potential of attaining greater energy output in watt-hours per pound for longer periods of cycling than other systems currently in use.

138. Doran, R. J.
THE NICKEL-SCANDIUM HYDROXIDE ELECTRODE.
In Proceedings 3rd International Symposium on Batteries, Bournemouth, Hants, October 1962, p. 105-116. New York, MacMillan, 1963.

This paper describes the effect of the scandium ion on the electrochemical behavior of nickel hydroxide, with particular reference to the improvement in performance of nickel-cadmium cells for satellites and other specialized uses.

139. Douthett, E. M.
In Szego, G. C. and Taylor, J. E. eds. Space Power Systems Engineering, p. 541-560, New York, Academic Press, Inc., 1966.

Review of the status of the SNAP-50/SPUR nuclear-electric space powerplant program as of September 1964. The concept behind the powerplant is treated briefly. It is considered that a suitable technological base already exists from which an orderly program can proceed, initially to feasibility demonstrations of the reactor

and power conversion components, and ultimately to a demonstration of an experimental powerplant. Nuclear-electric powerplants based upon this technology can have a variety of applications in the space program after 1975. Four potential applications are the unmanned electric propelled interplanetary spacecraft, lunar base power plants, electric propelled lunar logistic vehicles, and manned military satellite systems.

140. Dow, W. G.
SELECTED ENERGY-CONVERSION SUBSYSTEMS.
In Machol, R. E., Tanner, W. P. Jr., and Alexander, S. N., eds., System Engineering Handbook, p. 21-1 - 21-42. New York, McGraw-Hill Book Co., 1965.

A description of energy-coversion subsystems, using optimization principles, including thermoelectric conversion, thermionic conversion, magnetohydrodynamic generation, and controlled thermonuclear-fusion generation. Value-measures applicable to energy-conversion subsystems are discussed in terms of input-output efficiency, reliability, weight, geometric size, design man-hours required, and relative costs. The principles underlying conversion from thermal sources, voltage profiles in solid-state materials, practical thermoelectric conversion design and plasma converters are described. The future possibilities of thermo-nuclear-fusion reaction, as an effective source of electric power, based on the "ignition" of a plasma fuel by raising it to the critical ignition temperature, are discussed.

141. Dresser, D. L.
THE POTENTIAL OF SOLAR THERMIONICS FOR SPACE VEHICLE POWER.
[New York, Society of Automotive Engineers, 1963], n.p. (Paper 741B).

This paper summarizes theoretical and experimental results obtained during the past four years on the solar thermionic system. These results provide a basis for estimating the future competitive position of the thermionic system versus solar cells in space power. The basic characteristics of the system are outlined and recent developments are reviewed. A comparison is made of the thermionic and solar cell as power sources.

142. Drexel, C. F.
"HYDROX" CELLS AND NUCLEAR ENERGY FOR SPACECRAFT APU'S.
Aviation Age, 30:140-143, illus., Jly. 1958.

Discusses nuclear energy and solar battery power possibilities as auxiliary power systems for space vehicles.

143. Dryer, A. M. and Male, R. L.
EXCITER-REGULATOR FOR THE SNAP-8 SPACE POWER SYSTEM.
IEEE Transactions on Aerospace, AS-3, Suppl: 560-567, June 1965.

Description of a new static-exciter designed for the SNAP-8 electrical generating system - a nuclear-powered 80-kva 3-phase, 400-cps space power supply. The exciter-regulator incorporates many new features to meet the requirements for unattended long life in a radioactive space environment. The design criteria placed reliability far above weight, volume, and losses. The result is an exciter-regulator which promises to be more reliable than a similar conventional aircraft system by several orders of magnitude.

144. Dudley, W. L.
UNSYMMETRICAL LOW VOLTAGE CONVERTER.
In Power Sources Conference Proceedings, 18th, May 19-21, 1964, p. 105-108. Red Bank, N. J., PSC Publications Committee, 1964.

A concept of using an unsymmetrical low voltage electrical converter with a single diode thermionic converter was outlined at the 17th Annual Power Sources Conference. The present discussion describes the design of a practical current driven power converter.

145. Duffie, J. A.
SOLAR ENERGY CONVERSION.
In AMU-ANL Conference on Direct Energy Conversion. Chicago, Ill., Nov. 4-5, 1963, p. 24-25, Dec. 1963. (ANL-6802).

Solar energy is a natural resource of tremendous magnitude but one which has characteristics which make its economic application difficult. Processes for energy conversion from solar to other energy forms are roughly classified as (a) thermal, or (b) "photon" processes.

146. Dunbar, W. G., Flugstad, M. and Wittmann, J. C.
EFFECT OF VARIATIONS IN MISSION AND VEHICLE CONSTRAINTS ON FUEL CELL SYSTEM OPTIMIZATION.
IEEE Transactions on Aerospace and Electronic Systems, AES-2, Suppl: 57-60. Jly. 1966.

The sensitivity of some constraint variations on minimum weight hydrogen-oxygen fuel-cell systems of the 1970-1980 time period were investigated. Relative changes in fuel-cell system component weights are shown for variations in mission and vehicle parameters and constraints such as power quality and quantity, operating environment and radiator area limitation. Examples show the relative effects on fuel-cell system minimum weight, of improving voltage regulation with voltage regulators and augmenting radiator cooling with evaporative water cooling.

147. Duncanson, John.
NUCLEAR FUEL FOR SPACE TRAVEL.
Nuclear Engineering, p. 165-174, Apr. 1962.

A review is given of nuclear power systems for space flight. Topics included are: fuel requirements, space loads, reactor selection, space flight, auxiliary power systems, and the American program. Auxiliary power systems discussed include: Transit IV-A, SNAP-8, SNAP-10A, and other direct conversion systems.

148. Dunn, P. D. and Hammerton, J. C.
SURVEY OF POTENTIAL DYNAMIC CONVERSION SYSTEMS OF ISOTOPIC POWER.
In Industrial Applications for Isotopic Power Generators, p. 497-516, Paris, European Nuclear Energy Agency, 1967.

A survey has been made of potential dynamic conversion systems which meet the need for small (below 10 kw), long life reliable power sources utilizing radioisotopes in order to determine the nature of further development required to promote its commercial exploitation. The survey covers availability and costs of radioisotope heat sources based on current and estimated future production costs. It reviews thermodynamic cycles and heat engines indicating the limitations and problem areas.

149. du Plessix, M.
ELEMENTS ET BATTERIES POUR APPLICATIONS SPATIALES [ELEMENTS AND BATTERIES FOR SPACE APPLICATIONS].
Technique et Science Aeronautiques et Spatiales, p. 435-437, Jly.-Aug. 1966. In French.

Description of a VR 3, 5 DS cadmium-nickel sealed battery for space applications. This battery, derived from a standard sealed battery and having the same geometry, consists of a cylindrical case of nickel steel provided at one end with a metallic stud (positive terminal) electrically isolated from the case (negative terminal) by a cermet disk bonded to the metal.

150. Dupont, J.
LES REACTEURS NUCLEAIRES DANS L'ESPACE POUR LA PROPULSION ET A FOURNITURE DE L'ENERGIE DE BORD [NUCLEAR REACTORS IN SPACE FOR PROPULSION AND ONBOARD POWER SUPPLY].
l'Astronautique, no. 1, p. 48-67, 1967. In French.

Discussion of the principle and characteristics of a nuclear propulsion system and review of different nuclear propulsion programs. Homogeneous and heterogeneous thermal reactors and fast reactors are described, and structural and supply problems in a nuclear propulsion system are examined. The Nerva propulsion system is briefly described. The general characteristics of onboard nuclear reactors are reviewed, and conversion systems including thermodynamic, thermoelectric, and thermoionic conversion systems are considered. American projects in the course of development including SNAP 2, 10A, 8, and 50, and the MPRE program are reviewed, and Russian and French projects are briefly mentioned.

151. Dutram, L. L. and Williams, E. W.
PRELIMINARY DESIGN FOR A 360 WATT RADIOISOTOPE THERMIONIC GENERATOR.
IEEE Transactions on Aerospace, AS-2:661-668, Apr. 1964.

Description of the preliminary design for a 360-watt radioisotope thermionic generator as a space power system for planetary missions. Curium 244 is used as the energy source, and the generator design concept allows for containment of the radioisotope under all possible conditions involving the Earth. Provision is made for helium gas generated in the decay of Curium 244 (alpha emitter). For these conditions the proposed design has a maximum specific weight of 254-lb/kw. The results of this study indicate that radioisotope thermionics offers promise of a versatile, compact, light weight and reliable means of supplying electrical power in space.

152. Eastwood, W. S., Mullett, L. B. and Putman, J. L.
AMERICAN MINIATURE NUCLEAR GENERATOR, SNAP III.
Nature 183:643-644, Mar. 7, 1959.

A note on a power supply system for telemetry apparatus in a space rocket. The decay energy of a radioactive Po capsule is converted directly to electrical energy by means of thermocouples, giving an output of 5 w with efficiency 8-10 per cent.

153. Eggers, P. E. and Best, R. E.
ANALYSIS AND WEIGHT OPTIMIZATION OF THERMOELECTRIC GENERATORS FOR SPACE APPLICATIONS USING DIGITAL COMPUTER TECHNIQUES.
In Institute of Electrical and Electronics Engineers, and American Institute of Aeronautics and Astronautics, Thermoelectric Specialists Conference, Washington, D. C., May 17-19, 1966, Proceedings. p. 17-1 to 17-11. New York Institute of Electrical and Electronics Engineers, Inc., 1966.

A digital computer program for the analysis of thermoelectric generators operable in a space environment has been developed. The program provides a versatile and comprehensive parametric analysis tool for the evaluation of generator designs characterized by the static heat-transfer operational mode and geometries of right-cylindrical configuration. The analysis is performed by calculating total generator weight as a function of the parameters governing generator components. The dominant factors affecting the weight of a radioisotopic thermoelectric generator (RTG) can be identified since the analysis can be rapidly and parametrically performed by the computer program over a broad range of RTG-operating conditions. These data can be identified since the analysis can be rapidly and parametrically performed by the computer program over a broad range of RTG-operating conditions. These data can be used to establish minimum, weight configuration for RTG applications and to direct, as well as evaluate, individual component improvement programs.

154. Eggleston, F. K. and Fuschillo, N.
FABRICATION OF FLAT PLATE SOLAR THERMOELECTRIC GENERATOR PANELS FOR NEAR-EARTH ORBITS.
IEEE Transactions on Aerospace, AS-3, Suppl.:674-680, June 1965.

Development of a practical thermomechanical configurational design for flat-plate thermoelectric generator unit couples (approximately 1 in. by 1 in.) and panels (approximately 3 in. by 3 in.). An account of the techniques used in fabricating these solar energy conversion devices is given. Resulting unit couples provide 3 watts/ ft^2 with a weight factor of 30 watts/lb for the couple and 15 watts/ lb for the panel form. Steady-state and thermal-cycle life tests indicate an output degradation of less than 10% in 2000 cycles. These results offer promise of lower-cost space power systems with special adaptability to missions not suited to photovoltaic cells. The fabrication of 3 by 3-in panels of nine unit cells giving 15 watts/lb is described.

155. Egli, P. H. and Sherman, G. W.
ENERGY SOURCES FOR FUTURE.
New York, Society of Automotive Engineers, 1963, 19p. (Paper 645B).

Conversion systems are discussed under following headings, of which 4 are direct conversion processes-thermoelectricity, thermionic emission, magnetohydrodynamics, photoelectric process, fuel cells, and dynamic energy conversion systems; characteristics of processes, advantages and problems involved; most of effort is directed toward military and space requirements, and solutions for most of problems appear likely; immediate use of new processes in vehicle propulsion seems unlikely, but developments are in sight which could have large industrial impact.

156. Egli, P. H.
HISTORY AND RECENT DEVELOPMENTS IN DIRECT ENERGY CONVERSION SYSTEMS.
In Materials Science and Technology for Advanced Applications, p. 371-407.
Englewood Cliffs, N. J., Prentice-Hall, Inc., 1962.

Improved power sources and energy conversion systems are an important long range national problem and of immediate military importance. Various direct conversion processes appear promising for the solution of some of these problems. In thermoelectricity, progress in materials has been good, but much remains to be done. Even at this stage a number of valuable thermoelectric devices can be constructed, particularly cooling devices ranging from small modules for temperature control of electronic parts to submarine air conditioning, and small size power generators for various remote locations including long lived satellite missions. Thermionic emission offers light weight power generators for large power supplies for relatively short missions. Magnetohydrodynamics is confronted with imposing problems associated with the high temperature require-

ments for operation of more than a few minutes duration. Important improvements are in sight, and continued progress is imperative to provide high density power sources for advanced weapon systems. Photoelectric processes show good improvements toward the goals of lower costs and performance in severe environments. Fuel cells offer exciting possibilities for uses ranging from the main power source for submarines to the auxiliary power on short time space missions.

157. Egli, P. H.
SPACE POWER SOURCES BY THERMOELECTRIC AND THERMIONIC EMISSION PROCESSES.
Fusees et Recherche Aeronautique, 18:21-22, 1962.

Of the several possible processes for converting heat to electricity directly, thermoelectricity and thermionic emission are the most promising and are receiving the most serious attention. These two processes are more likely to be complementary than competitive because of the difference of the temperature range in which they best operate. Ultimately it seems likely that the two processes may be operated in series with the thermionic process converting high temperature heat and thermoelectricity recovering the heat rejected at lower temperature.

158. Egli, P. H.
THERMOELECTRICITY FOR SPACE APPLICATIONS.
New York, American Rocket Society, 1961, 4p. (Preprint 2122-61.)

Survey of the current status of thermoelectricity, and of its space applications. Developments in thermoelectric materials are discussed and the characteristics of the most promising materials are outlined. It is shown that valid design concepts of thermoelectric converters are now available with (1) isotope or reactor heat sources, (2) unfocused solar energy, or focused energy from large or small collectors, and (3) either battery or thermal storage. In each case, the converter is shown to be lighter, less expensive, and of longer lasting reliability than other existing systems, but to have limitations in regard to size and efficiency.

159. Ehricke, K. A.
ON THE APPLICATION OF SOLAR POWER IN SPACE FLIGHT.
British Interplanetory Society Journal, 16:35-37, Jan.-Mar. 1957.

Summary of paper given at Seventh International Astronautical Congress in Rome, Sept. 1956.

160. Ehricke, K. A.
SOLAR POWER FOR SPACECRAFT.
Missiles & Rockets 1:44-46, illus., Nov. 1956.

Investigates some of the aspects of space operations by hydrogen in high-specific impulse solar power drives. The concept of pressure-stabilized spherical reflectors for water-oxyhydrogen conversion in space and the solar power drive itself, not only seem feasible, but such a system can be constructed without too much effort.

161. Eibling, J. A.
WHERE IS SCIENCE TAKING US?
Saturday Review, 44:50-51, Nov. 4, 1961.

An engine that runs on sunlight is described in an updated and expanded version of a talk given at the 1961 Rome conference on New Sources of Energy. Basic concept of engine, developed at Battelle Memorial Institute, is to trap concentrated solar radiation directly within the engine. Two major uses are foreseen: (1) to power extra-terrestrial space vehicles, and (2) to provide a cheap, sturdy, simple source of power for under developed countries.

162. Eidelmann, D. and Guennoc, H.
PROBLEMS POSED BY THE STUDY OF A RADIOISOTOPIC GENERATOR OF ELECTRICITY FOR SPACE.
In Industrial Applications for Isotopic Power Generators, p. 415-24. Paris, European Nuclear Energy Agency, 1967. In French.

A study was undertaken to develop a 10 W(e) space generator prototype using a heat source of ^{90}Sr titanate. The conversion of heat into electricity would be made by means of doped Ge-Si thermocouples. In this study various points of view were examined: (1) minimum mass for fixed operational conditions; (2) flexibility of operation higher than a minimum fixed value for the duration considered; (3) structure compatible with admissible norms for various possible accidents; and (4) integration of the generator to the rocket or satellite. The study considered only the first point of minimum mass for 5-years' operation at 19 W(e). The number of thermo-elements used, the cold temperature of the thermo-element, hot temperature of the thermo-element, materials chosen and arrangement adopted, and geometric form of the radioactive source were the parameters selected in the study. The work program and the first physical measurements in the study are reported.

163. Einfeld, K. and Lauffher, R. A.
ABGRENZUNG DER ANWENDUNGSBEREICHE VON RADIOISOTOPEN-QUELLEN UND KERNREAKTOREN ALS ENERGIEQUELLEN FUR RAUMFLUGKORPER [LIMITATIONS OF THE APPLICATION OF RADIOISOTOPE SOURCES AND NUCLEAR REACTORS AS ENERGY SOURCES FOR SPACE VEHICLES]
In Energy supply in Space; Deutsche Gesellschaft Fur Raketentechnik und Raumfahrt, Symposium, Stuttgart, West Germany, December 8, 1965, Lectures[Energieversorgung im Weltraum; Deutsche Gesellschaft fur Raketentechnik un Raumfahrt, Symposion, Stugtgart, West Germany, December 8, 1965, Vortrage]. Vl. 2, p. 135-149. Munich, Deutsche Gesellschaft fur Raketentechnik und Raumfahrt, 1966.

Discussion of the characteristic differences between reactor and radioisotope systems as energy sources for space vehicle applications. The use of these two types of systems should be determined by their performance. Three performance ranges can be pointed out of which only the middle one, with initial values of from several hundred watts to several kilowatts, can be used under certain limiting conditions by both nuclear energy supply systems.

164. Eisenberg, M.
A SECOND REDOX TYPE.
In Power Sources Conference. Proceedings, 13th, 1959, p. 114-119, Fort Monmouth, N. J., U. S. Army Signal Research & Development Laboratory, Power Sources Division, 1959.

This paper is concerned with the electrochemical kinetics aspects of redox couples and the criteria for selection of couples for fuel cell applications. It is the belief of the writer that redox-type fuel cells are basically advantageous for space flight applications. These advantages are listed.

165. ELECTRIC POWER CAN BE GENERATED DIRECTLY FROM HOT GASES IN A NEW DEVICE - THE MAGNETOHYDRODYNAMIC GENERATOR.
Chemical Week, 85:70, Nov. 7, 1959.

Description of a device unveiled by General Electric. "Based on a principle discovered over a century ago by Michael Faraday, the unit has no moving parts, operates at temperatures high enough to ionize the gas to a plasma. Efficiency of converting thermal energy into electric power by the new method is expected to range between 40-50 o/o. compared with about 35 o/o efficiency of conventional turbo-generators. Magnetohydrodynamic generators capable of operating on the hot exhaust gases of rocket engines are believed to be feasible. Missile-borne generators capable of continuous operation, using solar or nuclear heat sources, will require several years to perfect, and magnetohydrodynamic power for general use is at least two decades away."

166. Ellern, F.
CAPACITY CHARGING CIRCUITS FOR SPACE SYSTEMS USING SILICON-CONTROLLED RECTIFIERS.
IEEE Transactions Aerospace, AS-2:505-508, Apr. 1964.

Silicon-controlled rectifiers were used in a capacity-charging circuit for applications in space where high efficiency and low weight are major considerations. This charger can be used to pulse lasers, plasma propulsion engines, sonar, or some thermonuclear devices. The system was compared to conventional designs and found to be particularly advantageous when the discharge rate was varied, or when the ratio of the capacitor charging period to the supply voltage period was high.

167. Elliott, D. G.
MAGNETOHYDRODYNAMIC POWER SYSTEMS.
Journal of Spacecraft and Rockets, 4:842-846, Jly. 1967.

Discussion of the potential offered by liquid-metal and plasma MHD systems for power generation in space environments. The ability to generate power from a simple gas- or liquid-cooled reactor using no rotating parts, at temperatures limited only by static materials limitations is very great. The two types of MHD systems discussed are the Rankine cycle and the Brayton cycle. The Rankine-cycle type uses cesium as the thermodynamic working fluid and lithium as the electrical working fluid. Operating conditions for a 300-kw, 2260°R system are indicated. Another MHD system, using NaK in place of lithium, is compared to the Li-Cs system, and the problem of thermally insulating the stators of both systems from the liquid metal is examined. One type of plasma MHD system, a Brayton cycle using argon as the working fluid, is investigated. A 3900°R reactor temperature is the value required for the Brayton cycle to have about the same radiator area as a 10% efficient Rankine cycle with a 2500°R reactor temperature and is also a temperature at which good argon conductivity can be attained. Numerous references to work concerning both types of systems are given.

168. Elliott, D. G., Cerini, D. J., Hays, L. G, and Weinberg, E.
THEORETICAL AND EXPERIMENTAL INVESTIGATION OF LIQUID METAL MHD POWER GENERATION.
In Electricity from MHD; Proceedings of a Symposium on Magnetohydrodynamic Electrical Power Generation, Salzburg, Austria, July 4-8, 1966. vl. 2, p. 995-1018,1105, Vienna, International Atomic Energy Agency, 1966.

Theoretical and experimental investigation of liquid-metal MHD power generation for space vehicle use. The type of end-effect correction known as the "compensating pole" technique is studied, in which an oscillating magnetic field is applied to the fluid entering and leaving the generator to make the flux linkages within the generator the same as those in a rotating or "infinite" generator. An experimental one-wavelength generator employing compensating poles has been fabricated, and empty-channel magnetic field measurements were made as well as dc measurements to determine the field profile as a function of phase angle and ac measurements to investigate the synchronization of the compensating liquid MHD cycles and working fluids, and these cycles are reviewed and compared. From the cycle studies it is concluded that the cesium-lithium separator cycle is the one most likely to achieve efficiencies greater than 5%, and from the indiction generator studies it is seen that only compensated generators with electrical lengths of three wavelengths or less are capable of generator efficiencies greater than 50%.

169. Elliott, J. F.
PHOTOVOLTAIC ENERGY CONVERSION.
In Sutton, G. W. ed., Direct Energy Conversion, p. 1-37, New York, McGraw-Hill Book Co., 1966.

Discussion of the physics of the photovoltaic effect and the application of the phenomenon to the conversion of solar radiation to electrical energy. A "pictorial" explanation of the device is presented, followed by a more exact discussion based upon the semiconductor junction diode equation. It is considered that with this basic understanding, it should be possible to appreciate the fundamental limitations of the device, as well as the reasons for the directions of current development activities. Several development programs are examined, and attention is given to present-day technology.

170. Emmerich, W. S.
MHD: ITS FUTURE POTENTIAL.
Energy International, 1:14-17, Apr. 1964.

The basic theory and applications of MHD power generation are discussed.

171. Engelhardt, R. A.
OPTIMIZED SOLAR-ARRAY-BATTERY - SPACE POWER SYSTEM.
In Institute of Electrical and Electronics Engineers, Annual East Coast Conference on Aerospace and Navigational Electronics, 12th, Baltimore, Md., October 27-29, 1965. Technical Papers, p. 1.2.3-1 to 1.2.3-6. New York, Institute of Electrical and Electronics Engineers, 1965.

Description of a regulator for ensuring maximum utilization of the power available from a solar cell array. A load-voltage battery charger is described which optimizes the power utilization of an array and provides substantial reduction in array size. The regulator ensures a constant load voltage over the day/night cycle, provides a rapid charge of batteries, and conserves energy by holding a constant load voltage.

172. Epstein, A. S and Groves, W. O.
SINGLE CRYSTAL GALLIUM PHOSPHIDE SOLAR CELLS.
Advanced Energy Conversion, 5:161-172, Jly. 1965.

Solar cells have been fabricated from epitaxially deposited single crystal gallium phosphide. Two types of cells have been found: (1) those having their major spectral response at about 0.75 μ and referred to as extrinsic, and (2) those which have their main response at 0.45 μ and are referred to as intrinsic cells. For the extrinsic cells, at 23°C in sunlight, an open circuit voltage (V_{oc}) of about 0.6 v with a short circuit current density, J_{sc}, of 4 ma/

cm^2 have been obtained with a conversion efficiency, measured in sunlight, up to 1%. Cell areas have ranged from 0.2 cm^2 to 0.5 cm^2 With increasing temperature, the V_{oc} of both types of cells decreases with a temperature coefficient, β of about 3 mv/deg. The Jsc of the 0.45 μ cell increases with temperature and the temperature variation can be expressed as $J_{sc} \sim \exp -(\Delta E/kT)$ with $\Delta E \sim .05$ ev. The extrinsic cell, on the other hand, shows no change in J_{sc} to 200°C, after which it decreases rapidly. The p-n junctions of these cells appear to be graded as evidenced by the capacity-voltage (c-v) relation which suggests a $1/c^3$ variation with voltage. From measurement of the minority carrier diffusion length using the technique of Logan and Chynoweth the minority carrier lifetime in these cells is found to vary between 10^{-10} and 10^{-12} sec.

173. Escoffery, C. A. and Werner, L.
OPTICAL CHARACTERISTICS OF SILICON SOLAR CELLS AND OF COATINGS FOR TEMPERATURE CONTROL.
Solid State Journal, 2:25-31, figs., Jan. 1961.

Silicon photovoltaic cells, which are widely used in space vehicles for the direct conversion of solar radiation into electric power, exhibit an undersirable decrease in power output with increase in cell temperature. This article discusses the control of cell temperature in terms of the absorptance and the emittance of solar radiation by the cell surface. Using measured values of spectral reflectance to 25 microns these parameters are determined for uncovered cells and for cells provided with glass filters and with silicon oxide films.

174. Euler, J.
DIREKTE ENERGIEUMWANDLUNG [DIRECT ENERGY CONVERSION]
Brennstoff-Warme-Kraft, 17:139-142, Mar. 1965. In German.

Review of the proceedings at the Lausanne Conference on Direct Energy Conversion. The current status and developmental trends of galvanic fuel cells, fuel cells employing fused salts as the electrolyte, the MHD generator, thermionic converters, and superconducting electric conductors (superconducting spools for magnets and superconducting dc cables) are examined, The application of the MHD generator and thermionic converters in combination with nuclear reactors and thermal power plants is discussed.

175. Euler, J.
THE PRESENT STATE OF DIRECT ENERGY CONVERSION.
Atom und Strom, 11:21-28, Mar. 1965. In German.

The present state of direct energy conversion is discussed. Both the isotopic battery and thermoelements have been developed to a usable stage. Galvanic fuel cells are ready for development,

although the technological difficulties are great. The thermionic converter is still not out of the research stage, although prototypes have operated satisfactorily for more than a thousand hours. The MHD generators are at the beginning of their development. The properties and functions of each of these are discussed.

176. Evans, G. E.
RELIABILITY-ENGINEERING OF FUEL CELLS FOR SPACE POWER.
New York, American Institute of Aeronautics and Astronautics, 1964, 13p. (Paper 64-746).

Presentation of a method for maximizing fuel-cell reliability while minimizing weight for a specified space mission requirement. The method calls for the following: (1) establishment of a conceptual design employing the simplest and fewest components possible; (2) selection of operating modes to permit self-regulation - i.e., design for intrinsic stability, rather than attempting positive control of instability; (3) selection of materials, parts, and components with maximum tolerance to abuse or to out-of-specification conditions; (4) employment of conservative design values, permitting major loss in component peak performance without approaching critical specification limits; (5) employment of modular design, where possible, with decoupling of interactions between modules so as to provide for varying degrees of partial system failure; (6) performance of tests over a much wider range of operational and environmental conditions than those specified by mission requirements; and (7) refusal to allow increases in power density or other performance ratings unless this can be accomplished without violating the above precepts.

177. Evans, J.
SOLAR CELLS.
British Interplanetary Society Journal, 19:62-67, May-June 1963.

The basic principles of conversion of sunlight into electrical energy in a semi-conductor p-n junction are described. From the theory, prediction of the expected performance as a function of external and internal parameters is made, and the maximum efficiency for a number of likely semiconductors quoted. Practical results are given for typical arrangements, including space projects already successful and proposed for the future. The effects of the space environment on performance and life are discussed. Finally, the direction and promise of future developments are indicated.

178. Evans, W. H., Mann, A. E., Weiman, I. and Wright, W. V.
SOLAR PANEL DESIGN CONSIDERATIONS.
In Snyder, N. E. ed., Space Power Systems, p. 79-109. New York, Academic Press, 1961.

The requirements and parameters of photovoltaic solar array design for space applications are presented. Electrical power requirements are discussed.

179. EXOTIC POWER SOURCES, THE BIG R&D PROBLEM IS BETTER MATERIALS. Electronics, 35:26-27, Aug. 31, 1962.

Developers see 10,000-hour lives for thermionic converters in space use. Engineering progress in all of the exotic power sources was reported at the Pacific Energy Conversion Conference. But speakers saw years more work-with better materials the chief problem-before the promises of direct conversion paid off.

180. Faehnrich, J. and Tomkova, E.
THERMIONIC ENERGY CONVERTER IN MAGNETIC FIELD.
Czechoslovak Journal of Physics, Sec. B, 15:276-286, 1965.

The paper deals with the influence of a magnetic field on the function of a thermionic energy converter. It derives a relation for the effect of the magnetic field on the converter current in a diffusion regime and gives measurements for a quasi-vacuum and diffusion regime of the converter.

181. Faget, M.
MANNED SPACE FLIGHT.
New York, Holt, Rinehart and Winston, Inc., 1965. 176 p.

Among the topics discussed is electrical power generation in space.

182. Fanger, J. B. and Nocera, J. R.
SPACE VEHICLE ELECTRIC POWER SYSTEM TEST MOCK-UP.
In Institute of Electrical and Electronics Engineers, Annual East Coast Conference on Aerospace and Navigational Electronics, 12th, Baltimore, Md., October 27-29, 1965. Technical Papers. p. 1.5.1-1 to 1.5.1-6. New York, Institute of Electrical and Electronics Engineers, 1965.

This paper describes a completely automatic space electric power system consisting of advanced design components which have been built and tested. The system has been incorporated into a test mock-up which permits simulation of abnormal conditions in the system and observing system performance. Various direct current power source volt-ampere characteristics can be simulated from programmable power sources. The test mockup can accommodate future system component designs for testing and evaluation. The system configuration is not necessarily advocated by the authors for any particular mission. The actual system configuration will be dictated by mission requirements.

183. Farrar, J., Keller, R. and Mazac, C. J.
HIGH-ENERGY BATTERY SYSTEM STUDY.
In Power Sources Conference Proceedings 18th, May 19-21, 1964, p. 92-94. Red Bank, N. J., PSC Publications Committee, 1964.

The purpose of this investigation was to select pairs of anodes and cathodes for a primary battery which will supply at least 200 watt-hours per pound. Lithium excelled in performance over magnesium for the anode series tested. However, its stability in the organic electrolytes has not yet been established. Magnesium has lower potentials than lithium but they are still acceptable. The magnesium anode showed promising current efficiency but the experiments revealed that the problem of delayed action also exists in organic electrolytes. Manganese dioxide in a solution of potassium thiocyanate in acetonitrile showed the best performance of the combinations under investigation. However, the polarization is presently still greater than that obtained in an aqueous solution. There is promise that a cell can be developed which will meet the specifications of 200 watt-hours per pound.

184. Ferguson, R. B.
ELECTRICAL POWER SYSTEMS.
In Purser, P. E., Faget, M. A., and Smith, N. F. eds., Manned Spacecraft - Engineering Design and Operation, p. 179-191. New York, Fairchild Publications, Inc., 1964.

Discussion of methods being developed for the generation of auxiliary electrical power for spacecraft. Chemical, nuclear, and solar energy sources are considered. Static energy-conversion systems covered include primary batteries, fuel cells, photovoltaic solar cells, and thermoelectric and thermionic sources. Dynamic systems covered include chemically-fueled expansion and internal-combustion engines, and Rankine-, Stirling-, and Brayton-cycle nuclear and solar systems. Factors involved in selecting a power system for a given mission are discussed, and include weight and reliability requirements.

185. Finck, C. R.
SNAP 9A - SIGNIFICANT DEVELOPMENT FACTORS AND LAUNCH APPROVAL.
In Szego, G. C. and Taylor, J. E. eds., Space Power Systems Engineering, p. 573-579, New York, Academic Press, Inc., 1966

The paper concludes that integration of isotopic power supplies with spacecraft should occur early in program definition rather than after the design of the spacecraft is frozen.

186. Fischbeck, K. H.
MAGNETOHYDRODYNAMIC POWER GENERATION - STATUS AND PROSPECTS.
In Direct Energy Conversion, p. 32-35. New York, Radio Corporation of America, 1963.

Discussion of the present state of the art of MHD electric power generation, in terms of the basic principles and applications. The fundamental properties and scaling laws of MHD generation are outlined. Three methods for obtaining appropriately high electrical conductivity to yield temperatures of 3000°C in an MHD channel are outlined, including: (1) the use of heat exchangers; (2) the incorporation, with the power station, of an oxygen plant, such that the combustion of the fuels takes place in an oxygenated atmosphere; and (3) use of the so-called frozen-flow expansion nozzle. It is noted that the high temperature at which MHD generators reject heat enables use of small radiators, and, hence, the possibility of very powerful, yet low weight, power systems, especially desirable for space applications. In space, MHD generators would be driven by fluids heated by nuclear reactors. Systems outlined include liquid metal, metal vapor, and high-temperature gas generator systems.

187. Fischell, R. E.
EFFECTS OF PASSIVE ATTITUDE CONTROL ON SOLAR POWER SYSTEMS.
In Interagency Advanced Power Group, Background Material for the Study of the National Space Power Program, v. 6, 1964, p. VI-B-1-VI-B-13. Oct. 1964. (PIC 120/6).

There is a strong relationship between a spacecraft's attitude control system and its capability for generating electrical power from solar cells. The effects of four particularly interesting passive attitude control techniques on the spacecraft's solar power system are discussed. These four techniques are: solar stabilization, spin stabilization, magnetic stabilization and gravity gradient stabilization.

188. Fisher, J. H. and Menetrey, W. R.
COMPARISON OF ENERGY CONVERSION SYSTEMS.
In Power Sources Conference, Proceedings, 14th, p. 94-96, Red Bank, N. J., PSC Publications Committee, 1960.

A comparison was made of various energy conversion systems (batteries, fuel cells, nuclear- and solar-energy sources, etc.) on the basis of space satellite power requirements. Only nuclear- and solar-energy sources can meet these requirements over long periods of time, and all the possible combinations of conventional energy forms (thermal or electric) and conversion techniques (heat engines, photovoltaic cells, thermionic converters, etc.) with nuclear- and solar energy sources were evaluated with respect to reliability, weight, availability, growth potential, cost, hazard, and life for 5- and 30-kw systems. The weighted evaluations show that no single system is outstandingly superior or inferior and that choice of a system should be made on the basis of its development. However, the solar Stirling engine and nuclear thermionic systems appear to be desirable for use as 5- and 30-kw systems, respectively.

189. Fisher, J. H. and Menetrey, W. R.
POWER IN SPACE: PROBABLE SOLUTION - A SOLAR POWER PLANT.
Mechanical Engineering, 81:49-51, Nov. 1959.

Discussion of power sources covering solar energy, the photovoltaic cell, the solar turboelectric system, and nuclear systems considering such problems as shielding, heat rejection, and meteoroids.

190. Flicker, H., Loferski, J. J. and Elleman, T. S.
CONSTRUCTION OF A PROMETHIUM-147 ATOMIC BATTERY.
IEEE Transactions on Electron Devices, ED-11:2-8, Jan. 1964.

Experiments conducted led to the conclusion that a long-life, small power source can be constructed by combining Pm^{147} with n/p silicon cells.

191. Ford, F. E.
AN AUTOMATIC BATTERY FORMATION SYSTEM.
In Institute of Electrical and Electronics Engineers, Annual East Coast Conference on Aerospace and Navigational Electronics, 12th, Baltimore, Md., October 27-29, 1965. Technical Papers, p. 1.5.3-1 to 1.5.3-4. New York, Institute of Electrical and Electronics Engineers, 1965.

Description of a procedure for forming silver-cadmium electrochemical cells in a manner which optimizes their use in a satellite power source. For the optimum design of a power source, cells of similar ampere-hour capacity at a common voltage terminal must be chosen. An automatic battery formation system is described which can form up to 20 cells simultaneously and verify that they have the similar characteristics required.

192. Fossen, P.
POWER IN SPACE: NEW DEVELOPMENTS SEEN PROMISING.
Missiles & Rockets 4:36,38,40,42,45, illus., Nov. 3, 1958.

Reviews some of the more important electrochemical, solar and nuclear power systems and discusses what can be expected of them.

193. Fouad, A. A. and Walsh, E. M.
A CYCLIC ANALYSIS OF THE GABOR-TYPE AUXILIARY DISCHARGE THERMIONIC CONVERTER.
Advanced Energy Conversion, 5:71-81, May 1965.

A cyclic analysis of a Gabor-type auxiliary discharge thermionic energy converter is presented. An overall charge balance for the system is believed to be the key in understanding the behavior of the ions and hence the converter performance. The analysis takes into account the phenomenon discovered by Gabor of the reflection of slow ions at the electrodes. A so-called critical equation is developed and discussed.

194. Fowler, G. A.
AEROSPACE SAFETY OF ISOTOPIC AND REACTOR POWER SOURCES.
Paper Presented at Geneva, Switzerland, United Nations, 1964. 15p. (Paper 28/P/286).

Description of safety considerations for radioisotope and reactor-type SNAP auxiliary power systems for space applications. Safety requirements and problems for aerospace nuclear power units for all phases of the handling of the power supply, from initial factory assembly through launch and possible Earth re-entry, are considered, including possible launch pad accidents and launch aborts. In addition, plans for research programs and the results of re-entry flight tests are described.

195. Frank, H. A.
ELECTRICALLY-REGENERATIVE HYDROGEN-OXYGEN FUEL CELL.
American Rocket Society Space Power Systems Conf., Sept. 25-28, 1962, 5p., Santa Monica, Calif., 1962. (ARS Paper 2563-62).

A description is presented of the status of electro-optical systems in the development of an electrically regenerative hydrogen-oxygen fuel cell for space application. The system performs the same function as a secondary battery in spacecraft, and shows potential advantages over batteries from standpoints of energy-to-weight ratio, cycle life, and operating temperature range.

196. Franks, R.
DESIGN OF ELECTRIC INTERCONNECTING CABLES AND CONNECTORS FOR SPACE POWER SYSTEMS.
IEEE Transactions on Aerospace, AS-3:14-21, Feb. 1965.

Illustration of the steps necessary to develop interconnecting electric cables which are adequate for use in space. A typical electrical power system for space use is described. The functions of electronic, mechanical, and production engineers in designing such systems are discussed, and the cable environment is examined with reference to the requirements that cables must withstand high vacuum, radiation, vibration, acceleration, and thermal stress. Various possible interconnecting systems are considered, possible causes of failure are evaluated, and insulating materials are assessed. Comment is made that an intercabling system of high reliability is an optimum blend of applicable materials with conformity to the geometric configuration and electrical requirements of the spacecraft.

197. Freedman, S. I.
HEAT-TRANSFER CONSIDERATIONS IN SPACE POWER SUPPLIES.
In Rohsenow, W. M., ed., Developments in Heat Transfer, p. 389-421, Cambridge, MIT Press, 1964.

Discussion of the methods being used in the solution of the problem of external heat rejection in existing and contemplated space power systems. Predictions of future power sources, their operational availability, and specific weights are shown, together with a map indicating the region of applicability of the various systems. It is shown that, in long-duration missions, power can only be economically made from solar or nuclear energy. The efficiencies of some of the available thermoelectrical materials are indicated. It is noted that, until space power requirements become large enough so that multimegawatt power systems are needed, space reactors will fall in the critical-mass fixed-weight category. The adoption of electric propulsion will be the deciding actor in the development of large space power systems.

198. Freytag, J. P., Grauleau, D. and Moncorge, G.
APPLICATION POSSIBLE DES CONVERTISSEURS THERMOIONIQUES A PLASMA DE CESIUM A L'ENERGIE SOLAIRE [POSSIBLE APPLICATION OF CESIUM-PLASMA THERMIONIC CONVERTERS TO SOLAR ENERGY].
Cooperation Mediterraneenne pour l'Energie Solaire, Bulletin 9:19-28, Dec. 1965. In French.

Examination of the possibility of heating the emitter of thermionic converter by solar energy. Following a review of certain information concerning energy detectors, the development of a converter is described. Results obtained with a carbon arc simulator are discussed. The electric power obtainable if the converters are heated by solar energy in space is determined.

199. Fuechsel, K. M.
DIRECT CONVERSION OF NUCLEAR ENERGY INTO ELECTRICAL OR THRUST ENERGY.
American Nuclear Society Transactions, 4:335-336, Nov. 1961.

Abstract of paper 32-7 given at winter meeting, November 7-9, 1961, Chicago.
A description is given showing how nuclear energy is converted directly into electrical or thrust energy.

200. "FUEL CELL" FOR PROPULSION: LOCKHEED MISSILE DEVELOPMENT.
Financial Times p. 9, Nov. 18, 1958.

Report of announcement by D. M. Eisenberg, of Lockheed Missile Systems Division, that Lockheed has developed "fuel cell" able to produce ten times the energy of equally heavy car storage battery. He predicted that, in five years time, the cell would be used to power cars, aeroplanes, and space vehicles. Details and nature of materials were not disclosed. The battery achieved almost 100% fuel utilization and efficiency of at least 70%.

201. FUEL CELL OBTAINS HIGH EFFICIENCY.
Electronics, 34:72, Nov. 24, 1961.

A wafer-type fuel cell, developed by the Armour Research Foundation of Illinois Institute of Technology, and which can supply electrical power in the high-temperature and radiation environment of outer space, is described briefly. Using hydrogen and oxygen for fuel, the cell is composed of an inorganic ion-exchanging membrane which operates at higher temperatures than the organic types now in use.

202. FUEL CELL USES BACTERIA TO PRODUCE POWER.
Missiles & Rockets 8:18, Apr. 17, 1961.

Refers to a cell, developed by Dr. Frederick D. Sisler, Department of the Interior Geological Survey biochemist, which produces electricity directly from the decomposition of organic matter. Potentialities for use in space as well as on earth are indicated.

203. FUEL CELLS GENERATE INTENSE INTEREST.
Chemical Engineering, 70:54-56, June 24, 1963.

A review of advances in the technology of fuel cells, plus a close scrutiny of their future uses are presented from a recent Army-sponsored conference on power sources.

204. Fujimoto, S.
EXPERIMENTAL RESEARCH ON THERMO-DIELECTRIC CONVERTER.
Institute of Electrical Engineers (Japan) Journal, 83:10-20, Dec. 1963.

A thermodielectric converter, a generator which utilizes the change in static capacitance of thermodielectric elements to effect direct conversion of thermal energy into electricity, is described. This paper reports on experimental results obtained through the use of the $BaTiO_3$ family of melt ceramics with a Curie temperature of approximately $22^{o}C$, covering both static and dynamic characteristics.

205. Fuschillo, N., Gibson, R., Eggleston, F. K. and Epstein, J.
FLAT PLATE SOLAR THERMOELECTRIC GENERATOR FOR NEAR-EARTH ORBITS.
Advanced Energy Conversion, 6:103-125, Apr.-June 1966.

Description of the theory, design, fabrication, and testing of flat plate thermoelectric generator panels for near-earth orbits. These panels are capable of producing 3 watts/ft^2 and 15 watts/lb when operating in such an orbit. The potential advantages of these solar energy converters, as compared to photovoltaic cells, are discussed. These include higher radiation resistance, improved power per unit weight, and lower cost on a per-watt basis.

206. Fuschillo, N., Gibson, R., Eggleston, F. K. and Epstein, J.
SOLAR THERMOELECTRIC GENERATOR FOR NEAR-EARTH SPACE APPLICATIONS.
IEEE Transactions on Electron Devices, ED-13:426-432, Apr. 1966.

The theory, design, fabrication, and testing of flat plate thermoelectric generator panels for near-earth orbits are described. These panels are capable of producing 3 watts/ft^2 and 15 watts/lb when operating in a near-earth orbit. The potential advantages of these solar energy converters, as compared to photovoltaic cells, are discussed and include higher radiation resistance, improved watts/lb, and lower cost on a per-watt basis.

207. Fuschillo, N., Gibson, R., Eggleston, F. K. and Epstein, J.
THEORY AND PERFORMANCE OF FLAT PLATE SOLAR THERMOELECTRIC GENERATOR FOR NEAR-EARTH ORBITS.
IEEE Transactions on Aerospace, AS-3, Suppl.:652-663, June 1965.

Description of the theory, design, fabrication, and testing of flat-plate thermoelectric generator panels for near-earth orbits. These panels are capable of producing 3 watt/ft^2 amd 15 watt/lb when operating in a near-earth orbit. The potential advantages of these solar energy converters, as compared to photovoltaic cells, are discussed and include higher radiation resistance, improved watts/lb, and lower cost on a per-watt basis.

208. Gaertner, W. W., Schuller, M. and Foodman, H.
MINIMUM-POWER MICROELECTRONIC SPACE SYSTEMS.
IEEE Transactions on Aerospace, AS-2:241-251, Apr. 1964.

Discussion of the design, fabrication technology, and performance of minimum-power microelectronic circuits and subsystems, some operating with a supply power consumption of only a few microwatts per transistor stage. The advantages of complementary pnp-npn circuitry are pointed out and figures of merit for minimum power circuitry are defined. The fabrication technology for micropower microelectronic circuits and its main advantages are outlined. Detailed examples of microwatt NOR gates, half shift registers and amplifier stages are given. Circuit and systems packaging and interconnection techniques are discussed. The design, construction, and performance of a minimum power seven-bit analog-to-digital converter and of a 10-channel record and playback amplifier system for a digital tape recorder, both destined for space applications, are described in detail. Advanced concepts such as the construction of complete subsystems on a single silicon wafer, the possibility of non-volatile operation with micropower semiconductor circuitry, and the departure from silicon as a host crystal and substrate to reduce stray capacitances are pointed out as research goals for the near future.

209. Gandel, M. G. and Kinsey, R. H.
HEAT DISSIPATION OF PRIMARY AND SECONDARY BATTERIES.
In AIAA Unmanned Spacecraft Meeting, Los Angeles, Calif., March 1-4, 1965, p. 190-195. New York, American Institute of Aeronautics and Astronautics, 1965. (AIAA Publication CP-12.)

Presentation of a method for the determination of thermal data for batteries employed in spacecraft power systems. An inexpensive calorimeter is used, and test results are presented for 30-ampere-hour, 25-volt nickel cadmium and 360-ampere-hour, 25-volt silver zinc batteries. The calculations employed are reviewed. It is found that heat-dissipation values for spacecraft batteries should be determined experimentally since there is insufficient theoretical basis for accurate predictions. The quantities of heat are shown to be significant, and it is recommended that they be considered in the thermal analysis of spacecraft. The high heat rates obtained on the overcharge of sealed secondary batteries are noted, and the necessity of limiting overcharge to prevent "thermal runaway" is emphasized. Although caution is advised in extrapolating the test results to other batteries, it is concluded that the presented values should allow reasonable approximations to be made for other battery designs using the same electrochemical systems.

Also in Journal of Spacecraft & Rockets, 2:996-998, Nov.-Dec. 1965.

210. Gardner, J. W.
DIRECT CONVERSION FOR SPECIALIZED APPLICATIONS.
Electrical Times 139:909-912, June 8, 1961.

The purpose of the article is to make a round-up of some of the less-publicized proposals for direct conversion which, although of marginal interest for large-scale commercial generation, appear promising for specialist applications requiring small units of high reliability in remote locations, e. g., space vehicles. The devices described are: the photovoltaic cell, the mechanoelectric converter, and the fission cell.

211. Garnier, R. C. and Koryu Ishii, T.
MICROWAVES POWER NEW MOTOR SYSTEM.
Electronic Engineer, 25:54-56, Aug. 1966.

Description of a motor powered by microwaves from inside a waveguide. The motor is basically a special dc motor without a commutator that is run by rectified rf energy obtained by the antenna pickup probe inside a waveguide. The principles, actual arrangement, and experimental results are detailed. The waveguide motor circuit used in the research is shown, as is a block diagram. The circuit was made so that continuous rotation was maintained by five steps: (1) the antenna probe receives rf energy, (2) a diode rectifies the rf energy, (3) a capacitor and inductor form a filtering network to increase the rotor coil current, (4) the rotor coil produces a magnetic field that reacts with the permanent magnetic field, and (5) at the proper position in rotation, the antenna cuts itself off from the impinging rf field so that no reaction between the rotor coil and permanent magnet can exist. Suggested applications include powering space vehicles and remote-controlled vehicles, and the system may be useful in servomechanism and instrument motors engineering.

212. Garrett, A. B.
BATTERIES OF TODAY
Dayton, Ohio, Research Press, Inc. 1957, 216 p.

Principles and operation of storage, primary, solar, and nuclear batteries, and classical and fuel cells.

213. Gauvenet, A.
ENERGIE DE SERVITUDE A BORD DES VEHICULES SPATIAUX (POWER FOR THE SUPPLY OF DEVICES INSTALLED ON BOARD SPACESHIPS).
In Moureu, H. and Bernard, M. Y., eds., Astronautique et Recherche Spatiale, p. 151-171, Paris, Dunod, 1964. In French.

Consideration of a durable source of power, independent of the powerplant, for the supply of instruments and devices installed on spaceships. The subjects discussed are the general characteristics of sources of instrument power in space, methods for the generation of power on board spaceships, and the different types of electric generators that can be installed on satellites, their practical characteristics, technical details, and applications. It is concluded that the available engineering and scientific facilities allow consideration of the use of a great many power sources suitable for all space missions.

214. Geisenheyner, S.
ENERGIE-SCHLUESSEL ZUM WELTRAUM (ENERGY CONVERSION IN SPACE).
Flug-Revue, p. 18-19, 36, Dec. 1961. In German.

Survey of advanced energy-conversion techniques for space power systems. Some developments in ion engines, plasma engines, solar and fuel cells, magnetohydrodynamic generators, and thermo-electric and thermionic converters are noted.

215. Getler, M.
NEW CELLS DUE FOR HEAVY SPACE DUTY.
Missiles & Rockets, 10:34-35, illus., June 11, 1962.

Nickel-cadmium units produces in NASA-sponsored pilot plant use ceramic-to-metal seals, non-woven nylon.

216. Getler, M.
SOLAR SPACE POWER, THERMIONIC FLIGHT EXPERIMENT STUDIED.
Missiles and Rockets, 12:38, 42-43, Apr. 29, 1963.

A study made here by General Electric Co. scientists indicates that an experimental solar thermionic power system, operating at about 5% efficiency with a 55-watt output, could be placed in orbit within two to two and one-half years.

217. Gettings, H.
ENERGY CONVERSION GROWS IN IMPORTANCE.
Missiles and Rockets, 5:22,24,42, Dec 7, 1959.

New stress on space and potential commercial uses gives impetus to search for more and better ways to convert energy directly to electricity. Thermoelectricity is mentioned as one of the areas of energy conversion interesting to the military and some of the work of ONR and NRL in this area is referred to.

218. Gettings, H.
PROSPECTS FOR THERMOELECTRICITY.
Missiles & Rockets, 5:29-31, illus., June 22, 1959.

Heavy investment in research gives hope for long-lived power units for space application.

219. Giacolleto, L. J.
ENERGY STORAGE AND CONVERSION.
IEEE Spectrum, 2:95-102, Feb. 1965.

Study of energy storage and conversion factors as indices of comparison between the various energy storage methods and energy conversion systems. Energy storage factors are very important for mobile applications and become critically important for space vehicles, where added energy is required to transport the fuel to be used and the terminal velocity of the space vehicle is directly related to the energy/mass storage factor of the fuel. Chemical fuels, as represented by gasoline, have roughly the same energy/-mass storage factors. The other methods of energy storage, except nuclear, have smaller energy/mass factors. In a complete system, the conversion efficiency and the power/mass factor of the conversion equipment contribute significantly to the overall effectiveness.

220. Gilmore, K.
FUEL CELLS.
Electronics World, 68:23-26, 82-85, Sept. 1962.

New exotic power sources will supply all electrical needs of space vehicles. These cells produce electricity directly from chemical reactions with efficiencies far greater than any other non-nuclear power system.

221. Ginger, D. A., Burton, J. S. and Farmer, G. C. H.
FURTHER OBSERVATIONS ON THE PERFORMANCE OF ZINC-SILVER CHLORIDE CELLS.
In Proceedings 3rd International Symposium on Batteries, Bournemouth, Hants, October 1962, p. 453-464. New York, MacMillan, 1963.

This paper is concerned with the probable mechanism of failure of the cells at elevated temperatures. The construction and the performance of improved, 50 mA-hr layer-type zinc-silver chloride cells are described.

222. Ginger, D. A., Burton, J. S. and Keene, D. E.
A RADIO-ISOTOPE POWERED BATTERY USING A KRYPTON-85 HYDROQUINONE CLATHRATE SOURCE.
In Collins, D. H., ed., Batteries 2; International Symposium, 4th, Brighton, England, September 29-October 1, 1964, Proceedings, p. 385-399, Oxford, Pergamon Press, Ltd., 1965.

Description of a radioisotope-powered battery which uses direct beta-particle collection to negatively charge an electrode. Considerations for the choice of isotope, dielectric, collector (anode), and shielding for the battery are reviewed. The isotope chosen was Kr-85, a gas which, while chemically inert, forms inclusion compounds or clathrates with certain host materials. The isotope source is a solid Kr-85/hydroquinone clathrate. The design and operation of the battery are described, and some possible low-energy applications for it are discussed.

223. Gingrich, J. E.
RADIOISOTOPE FUELED THERMIONIC SPACE POWER SYSTEMS.
IEEE Transactions on Aerospace, AS-2:669-674, Apr. 1964.

Parametric study of the heat source and system variables made in order to understand better the interacting variables of the radio-isotope fuel properties and the operating conditions for thermionic converters. Fuel bodies and converters of various geometric shapes were studied with planar, cylindrical, and spherical emitter surfaces. The problems relating to radiological safety and shielding was obtained for some of the more promising isotope fuels. The results of this study show that there is no completely ideal radioisotope heat source for thermionic space power systems and that the more promising isotope fuels will require important compromises between system specific weight, radiation shielding, system efficiency, and isotope containment to produce usable space power systems.

224. Gladstone, B.
SOLAR-ARRAY, BATTERY POWER SYSTEMS.
In Wescon/65; Proceedings of the Western Electronic Show and Convention, San Francisco, Calif., August 24-27, 1965, Technical Papers, Part 3 - Power Electronic. North Hollywood, Calif., Western Periodicals Co., 1965. 6p.

Study of the savings in satellite power systems which are now possible because of recent advances in component and black-box design. Two basically new components - Adhydrode nickel-cadmium and silver-cadmium cells, and high-frequency silicon power transistors - are described, and their advantages outlined; design criteria are shown and applied to a typical example. Some of the concepts described are said to be applicable to other types of satellite systems i.e. the idea of energy utilization can be applied to a fuel-cell battery system, and the concept of regulating the voltage to all major energy dissipators is valid for almost all satellites.

225. Glassman, A. J., Krebs, R. P. and Fox, T. A.
BRAYTON CYCLE NUCLEAR SPACE POWER SYSTEMS AND THEIR HEAT TRANSFER COMPONENTS.
Chemical Engineering Progress, Symposium Series, 61:306-314, 1965.

Discussion of the heat transfer components which constitute an important part of any Brayton cycle. The most promising power-generation technique for near future application to missions requiring power levels greater than several kilowatts for 1 yr or longer is the indirect conversion closed-loop heat engine. On the thermodynamic systems that merits consideration for such applications is the Brayton cycle, which uses an inert gas as the thermodynamic working fluid. Several configurations being considered for Brayton cycle space power systems are described, and the required heat transfer components are indicated. Important system characteristics such as cycle efficiency and radiator area are related to such heat transfer component parameters as reactor temperature, component-pressure drops, heat exchanger effectiveness, and radiator heat transfer coefficient. The heat transfer component features necessary to make a Brayton cycle attractive for space use are emphasized, and the ability of available heat transfer components to achieve the required performance and reliability is discussed.

226. GOLD GETS ROLE IN OUTER SPACE; GENERAL ELECTRIC USES HEAT FROM RADIOISOTOPES TO FUEL ITS THERMIONIC CONVERTER.
Chemical & Engineering News, 37:52, Feb. 9, 1959.

The thermionic converter "boils" electrons off its hot side and collects them on the cool side to produce an electric current. Efficiency at present is low, only 4%, but by designing the whole system for optimum use of heat and improving the converter, it is hoped to achieve 10%.

227. Gold, T.
SOLAR POWER IN SPACE. DESIGN PROPOSAL.
Astronautics, 6:34-35, illus., Feb. 1961.

Development of thin metalized plastic sheeting with many small holes for use of photoemitter and collector in space could conceivably permit generation of as much as 1 kw of power per 10 or 15 lb of weight.

228. Goldberg, D. C., Young, W. E. and Hundstad, R. L.
MATERIALS REQUIREMENTS FOR MAGNETOHYDRODYNAMICS.
Metal Engineering Quarterly, 3:47-54, Nov. 1963.

While it has been established that, theoretically, magnetohydrodynamics for power generation and propulsion is desirable and possible for both terrestrial and space uses, its realization as an economic means of power generation depends entirely on the development of suitable materials. Some of the critical materials requirements

include: capability of withstanding temperatures near 5000° F; chemical and physical inertness to alkali-seeded gas stream; resistance to thermal shock; resistance to erosion by high-velocity gas stream; thermal insulating properties; and the ability to serve either as an electrical insulator or a conductor as application may require.

229. Gomberg, L. and Thierfelder, H.
ASSURING RELIABILITY IN AEROSPACE BATTERIES.
In National Symposium on Reliability and Quality Control, 11th, Miami Beach, Fla., January 12-14, 1965, Proceedings. p. 459-469. New York, Institute of Electrical and Electronics Engineers, 1965.

Presentation of a program to assure the design, development and manufacture of reliable nickel cadmium batteries for such spacecraft as the Relay, Tiros, and Nimbus. It is emphasized that nickel cadmium batteries have three advantages over other types, resulting in an inherently more reliable battery cell: (1) extensive cycling life capability (upwards of 4000 cycles); (2) good overcharge capability; and (3) long-life plate materials. Failure modes and mechanisms, the defect prevention and detection program, design review, and reliability prediction are discussed. The internal shocks, stand, vibration, and capacity tests are considered in the discussion of failure detection. It is concluded that highly reliable nickel cadmium batteries are obtainable through the diligent selection of cells and the application of battery design to best suit the service required.

230. Goodyear, J.
POWER FROM THE SUN.
Ordnance 43:323-326, Sept/Oct. 1958.

Briefly refers to solar batteries for use in space technology.

231. Gordon, G. D.
A 30 KW POWER SUPPLY FROM THIN FILM SOLAR CELLS.
New York, American Institute of Aeronautics and Astronautics, 1964, 12p. (Paper 64-740.)

Proposal for a complete 30-kw powerplant that would weigh about 2500 lb, using 1% efficient solar cells with a power-to-weight ratio of 15 watts/lb. This includes the supporting structure, electrical connections, sun sensor, and attitude control, which add 25% to the weight of the individual cells; storage batteries and power regulation are not considered. It is stated that expected improvement in cell manufacture might reduce the weight to 800 lbs by the time the first array is launched. The usual concept of using thin-film solar cells has been to use high efficiency (5%-10%), large area cells, mounted on a rigid structure, inflatable sphere, or rotating disk.

Recent system studies show advantages in using existing low efficiency (1%), small area cells, with evaporated interconnections on a single plastic substrate. It is stated that a roll would be manufactured as a unit, unrolled in space, and held out by centrifugal force. The discussion includes the system parameters, required dynamics, attitude control effect, other effects of radiation pressure, and applicability for various missions.

232. Gould, C. L.
MULTI-KW SOLAR CELL POWER SYSTEMS.
New York, American Institute of Aeronautics and Astronautics, 1964, 10 p. (Paper 64-717.)

Review of representative space vehicle requirements and presentation of the effect of these requirements on power system optimization and design. It is stated that the optimization of power utilization, power conditioning, and energy storage techniques resulted in reduction of power demands to 16 kw (excluding major experiments and oxygen regeneration) for a 21-man space station. Over half of the power was required to be ac, primarily for lights, electronics, and motors. To maximize inverter efficiency, a +28-volt, 0, -28-volt system was selected to allow an inverter input voltage of 56 volts, while still having 28 volt dc busses. Solar array deployment schemes are discussed, including designs that use either flexible thin-film solar cells or a flexible through-type concentrator that can be wrapped around the vehicle during launch. The concentrator design is thermally optimized so that power gains up to 2.4 can be obtained with concentration ratios of 2.6, correspondingly reducing the number of solar cells required.

233. Gould, C. L
SOLAR CELL POWER SYSTEMS FOR SPACE STATIONS.
IEEE Transactions on Aerospace, AS-2:759-768, Apr. 1964.

Survey of space station power requirements and an optimized solar cell power system, including some of the characteristics of the solar cell array, energy storage system, and power conditioning system. The cost and complexity are reduced by using lower-cost cells, more efficient energy storage, power conditioning and power distribution systems, and by using a concentrator that can be wrapped around the vehicle for launch. Growth capability is obtained by adding a supplementary experimental power system for operational uses.

234. Gourdine, M. C.
DIRECT ENERGY CONVERSION AND ASTRONAUTICS.
In Anderson, T. P. and Springer, R. W., eds., Advances in Plasma Dynamics; American Institute of Aeronautics and Astronautics, and Northwestern University, Biennial Gas Dynamics Symposium, 6th, Evanston, Ill., August 25-27, 1965, Proceedings, p. 273-280. Evanston, Ill., Northwestern University Press, 1967.

Re-examination of previous notions about generating electric power in space. It is pointed out that there is no a priori reason to assume that the energy conversion techniques used so successfully on earth will solve the power problems to be faced in space. Astronautics is a science that will be practiced in a new, and possibly hostile, environment. Therefore, new power systems more compatible with conditions in space should be actively sought. It is concluded that direct-energy conversion, rather than conventional energy-conversion techniques, will have to play a major role in future astronautic systems.

Also issued as American Institute of Aeronautics and Astronautics. Paper 65-635.

235. Gourdine, M. C. and Larsen, H. M.
NUCLEAR-MAGNETOGASDYNAMIC POWER GENERATION FOR SPACE VEHICLES.
New York, Society Automotive Engineers, 1963, n.p. (Paper 741C.)

A nuclear-magnetogasdynamic (MGD) power generation system is described which is capable of satisfying the long-duration, high power level mission requirements of space vehicles. In this Rankine cycle system, radiofrequency (RF) electric fields are used to ionize a cool supersonic gas, and the Hall effect is used to generate electrical power. Following an analysis of MGD energy conversion and RF plasma production, preliminary design is made of an experimental system having a generator power density of 10 mega-watts/cu m in which 5% of the output power is used to produce the cool plasma.

236. Gradecak, V.
HIGHLIGHTS IN INCONVENTIONAL NUCLEAR POWER AND PROPULSION SYSTEMS.
IEEE Transactions on Nuclear Science, NS-12:229-239, Feb. 1965.

A survey of several unconventional concepts of nuclear power and propulsion systems which have been proposed during recent years. The unconventional aspects of these concepts reside partly in their indicated performance capability and partly in the scanty discussion they received thus far by other workers in the field. It is the objective of this survey to bring these proposals to renewed attention and discussion among those concerned with progress in space power and propulsion systems.

237. Grant, L. J.
POWER SOURCES FOR ORBITAL ROCKETS.
Journal of Space Flight 3:1-3, Nov. 1951.

Nuclear and solar sources are discussed.

238. Greenfield, H. H. and Kittleson, R. E.
SPACEPROBE RADIOISOTOPE THERMOELECTRIC GENERATOR POWER SYSTEM DESIGN CONSIDERATIONS.
American Nuclear Society Transactions, 4:161-162, June 1961.

The design of a spaceprobe power system is considered using multiple SNAP III type thermoelectric generators.

239. Gritton, D. G. and Bourke, R. C.
RADIOISOTOPE-PHOTOVOLTAIC ENERGY CONVERSION SYSTEM.
Advanced Energy Conversion, 5:119-145, Jly. 1965.

A radiant energy conversion (REC) system based on the electrical response of photocells to thermal radiation emanating from a radioisotope-fueled source is described. Some properties and optimization requirements of germanium photovoltaic cells are given. Principal elements of the system and analysis methods of the radiative exchange problem are described along with performance calculations. This system can operate with an efficiency greater than 4%. An upper limit of 12% can be calculated if efficiency values for the photocell are based only on the active cell area and the contacted area is neglected.

240. Groll, M. and Pruschek R.
TEMPERATURVERTEILUNG IN EINEM SCHNELLEN REAKTOR MIT THERMISCHEN KONVERTERN AN DER REAKTOROBER-FLAECHE [TEMPERATURE DISTRIBUTION IN A FAST REACTOR WITH THERMIONIC CONVERTERS ON ITS SURFACE]
Atomkern Energie, 10:383-391, Sept.-Oct. 1965. In German.

A power supply system for space, consisting of a fast reactor and thermionic converters (system SRAST), is investigated. Thermodynamic calculations for the nuclear-calculated reactor with known geometry and flux distribution are carried out. The temperature distribution in the reactor and the produced power are obtained by one- and two-dimensional calculations. The influence of parameters is discussed.

241. Grubb, W. T. and Niedrach, L. W.
FUEL CELLS.
In Sutton, G. W., ed., Direct Energy Conversion, p. 39-104. New York, McGraw-Hill Book Co., 1966. (Inter-University Electronics Series, vl. 3.)

Discussion of fuel cells, defined as electrochemical devices that directly convert the chemical energy of a fuel oxidation reaction into electrical energy. Fuel cells are considered from the point of view of thermodynamics which sets the ultimate limitation on energy density, from the point of view of the kinetics of electrochemical reactions and trasport processes which set practical limits on energy density and are subject to improvement, and from the point of view of the state of development of representative types of fuel cells. It is considered that fuel cells will always be very complex in the chemical sense, and there will be many types of possible fuel cells in keeping with the wide diversity of chemical reactions that may be involved.

242. Grun, C. and Sulkes, M.
HIGH-ENERGY AND RESERVE BATTERIES.
Machine Design, 35:211-218, Apr. 11, 1963.

Discussion of the construction and performance features of the silver-zinc and the silver-cadmium (alkaline) battery systems. The study of the first system covers the vented rechargeable type, the sealed rechargeable type, and the automatically activated and manually activated primary systems. Also discussed are two reserve primary systems: the silver chloride-magnesium and the cuprous chloride-magnesium types. A graphical comparison of the energy densities of silver-chloride and cuprous-chloride reserve primaries with the silver-zinc primary is presented.

243. Gruntz, R. D. and Rackley, R. A.
SNAP 50/SPUR POWER CONVERSION SYSTEM OBJECTIVES, CURRENT STATUS, AND LUNAR APPLICATIONS.
In Society of Automotive Engineers, Aerospace Fluid Power Systems and Equipment Conference, Los Angeles, Calif., May 18-20, 1965, Proceedings, p. 210-221,232. New York, Society of Automotive Engineers, 1965.

Detailed description of the Snap 50/Spur potassium Rankine-cycle power-conversion system technology including the status of development of the potassium boiler, potassium turbogenerator, condenser/radiator, pumps, and control system. Current test results and hardware are shown. A discussion of a potential lunar application and associated problems is included. Conclusions reached are that the high-temperature Rankine cycle with potassium as the working fluid is an excellent choice for applications of this nature because of the light weight, compact size, and simplicity inherent in this system.

244. Guilland, C. and Rodot, M.
LES CELLULES PHOTOVOLTAIQUES - REALISATIONS, PERSPECTIVES D'AVENIR [PHOTOVOLTAIC CELLS - ACHIEVEMENTS AND FUTURE PROSPECTS].
Cooperation Mediterraneenne pour l'Energie Solaire, Bulletin 8:152-161, May 1965. In French.

Review of the properties and performance characteristics of silicon and other solar batteries and a discussion of prospective developments in this field. In such batteries solar radiation gives rise to minority carriers (electrons or holes) in a heterogeneous structure consisting of a p-n junction. Manufacturing techniques for the production of Si solar batteries are described. A typical current-voltage curve is presented, and it is shown that at maximum efficiency the voltage = 0.45 v, while the current = 75 ma, for a 3-cm^2 battery illuminated by the sun at local noon in Paris. The spectral response for Si cells is illustrated. The short-circuit

current varies linearly with the intensity of the incident light. The theoretical efficiency of present Si batteries is about 16%, and about 19% for GaAs batteries. Experiments with CdTe in thin layers which exhibited the same electrical, optical, and photo-conductive properties as CdTe in the bulk state are described.

245. Gummel, H. K. and Smits, F. M.
EVALUATION OF SOLAR CELLS BY MEANS OF SPECTRAL ANALYSIS.
Bell System Technical Journal, 43:1103-1121, May 1964.

Outline of an approach for testing of solar cells, and description of a test set and evaluation procedure of test results. Outer space short-circuit current is calculated from spectral response measurements performed on the cells. From this, and from additional measurements that determine the forward diode-characteristic, the maximum obtainable power and the voltage at which maximum power is delivered are computed. It is stated that the accuracy of outer space short-circuit current predictions is $\pm$ 2 to 3% when suitable standards are employed.

246. Gustavson, J.
WHERE WILL ELECTRIC POWER COME FROM IN SPACESHIPS?
Aviation Age, 29:186-189, diags., Apr. 1958.

A discussion of the three most likely sources for power: chemical batteries, atomic batteries, and thermocouples.

247. Gyftopoulos, E. P. and Hatsopoulos, G. N.
THERMIONIC NUCLEAR REACTORS.
Electrical Engineering, 82:108-116, Feb. 1963.

A unique power system for space, submarine propulsion, and applications in remote areas should result from the successful coupling of nuclear reactors with thermionic converters. Three conceptual designs of thermionic nuclear reactors are reviewed to establish requirements for performance characteristics and materials and to pinpoint some of the problem areas.

248. Hagemann, E. R.
R. H. GODDARD AND SOLAR POWER 1924-1934.
Solar Energy, 6:47-54, illus., Apr./June 1962.

From 1924 through 1934, Professor Robert H. Goddard, primarily known for his rocket work, engaged in considerable research in solar power and conversion. He was granted five patents and constructed several laboratory test models of his various apparatus. Goddard's principal contributions were his correction of errors in the work of others and his conversion studies. He envisioned his work being applied both to space travel and to supply abundant and cheap terrestrial power.

249. Hagis, W., Dobry, T. and Dix, G.
NUCLEAR SAFETY ANALYSIS OF SNAP 3. FOR SPACE MISSIONS.
New York, American Rocket Society, 1960. 12p. (Technical Paper 142-60.)

SNAP-3 is an auxiliary power unit which converts the decay heat from radioisotope fuel into electrical power. Results are summarized of a study of the propagation of radiation from the fuel in case of post-orbital re-entry or an abort. Possible locations of impact were plotted. The effects of aerodynamic heating on the formation of radio-polonium aerosol were studied. Results indicate that SNAP-3 would be acceptable for operational missions.

250. Halas, E.
SUPERCONDUCTING POWER GENERATORS.
Ground Support Equipment, 6:19-21, 1964.

Discussion of the advantages expected to accrue from the use of of cryogenic, superconducting generators for military ground-based power-generation systems. It is indicated that, because theoretical power density is related to flux density by a square factor and because superconducting magnets can generate flux densities appreciably greater than conventional magnets, it is expected that new generators having advantages of low weight (and therefore high mobility) and reliability of operation will become available. Topics discussed include: recent developments, unit sizes and prime movers, normal generators and superconducting generator concept, alternator generator and inductor generator, normal conductors and superconductors, and the need for increased emphasis on development.

251. Halasz, D. and Szendy, K.
THE MEDIUM-POWER THERMIONIC GENERATOR.
Acta Technica, 48:125-141, 1964.

The design and conditions necessary for a medium-power thermionic generator are described.

252. Hamilton, R. C.
SOLAR POWER SYSTEMS.
New York, American Rocket Society, 1961. 6p. (ARS Technical Paper 2168-61.)

Describes briefly the characteristics of solar radiation, solar power system selection criteria, and optimization requirements. Also gives brief notes on solar concentrators, photovoltaic power systems, photoemissive solar converters, thermoelectric solar converters, solar thermionic converters, solar dynamic systems and energy storage.

253. Hamilton, R. C. and Laue, E. G.
SPACECRAFT SECONDARY POWER REQUIREMENTS DURING THE SIXTIES.
In Conference on Space Technology, Dallas, Tex., April 11-13, 1960. Papers. Electrical Engineering in Space Technology, p. 112-119, New York, American Institute of Electrical Engineers, Dec. 1960.

A summary of the secondary electric power during the 1960-65 period for a typical spacecraft is shown in a table. For the future, the reactor-powered thermoelectric converter known as SNAP-X which provides 200 to 300 electric watts appears attractive for some missions. Development of more rugged fuel cells for energy storage applications is proceeding, and will be needed during the sixties.

254. Hannemann, D.
EIN RADIONUKLIDGENERATOR MIT THERMIONISCHEM WANDLER [RADIO NUCLIDE GENERATOR WITH A THERMIONIC CONVERTER]
In [Energy Supply in Space] Deutsche Gesellschaft fur Rakententechnik und Raumfahrt, Symposium, Stuttgart, West Germany, December 8, 1965, Lectures, vl. 2, p. 221-234. Munich, Deutsche Gesellschaft fur Raketentechnik und Raumfahrt, 1966. In German.

Description of a proposed isotope battery or radio nuclide generator using the oxide of strontium 90 as the isotope charge. A description is given of the decay scheme of strontium 90, and a comparison is made between the specific powers of strontium 90 and its oxide as a function of time. The characteristics of a proposed thermionic converter capable of achieving an efficiency of about 15% are cited. A structural analysis is made of an isotope battery using the oxide of strontium 90 as the isotope charge and a thermionic converter to produce an output of 100 watts. Methods of ensuring good heat insulation, in order to achieve the desired heat-flux concentration, are suggested, as well as a method of ensuring a sufficiently large radiating surface to cool the collector of the thermionic converter. An estimate is made of the gammaradiation dose rate at a distance of 1 m from the isotope container, and shielding measures to decrease the radiation losses are suggested.

255. Hanson, K. L.
A SURVEY OF TECHNIQUES FOR PREDICTING THE SPACE OUTPUT OF PHOTOVOLTAIC DEVICES.
New York, American Society of Mechanical Engineers, 1962. 8p. (ASME Preprint Paper no. 62-WA-194.)

Major problem areas in predicting the output of photovoltaic power supplies for space vehicles are identified. The accuracy requirements are defined, and present methods of prediction are described and evaluated with respect to the requirements. It is concluded that refinement of present methods will be sufficient for future needs, but correlation and additional high-altitude experimentation are needed.

256. Harashima, O., Kano, Y., Tsuru, H. and Ono, H.
DETERIORATION OF SOLAR BATTERIES UNDER HIGH ENERGY ELECTRON BOMBARDMENT.
In Nomura, T., ed., International Symposium on Space Technology and Science, Tokyo, Japan, August 27-31, 1962, 4th Proceedings, p. 718-723. Tokyo, Japan and Rutland, Vt., Japan Publications Trading Co., 1963.

Description of a laboratory electron bombardment test on solar cells conducted for the purpose of obtaining basic data for the estimation of the life of solar cells in space. Due to the fact that, in space radiation, protons are much less numerous than electrons, the studies were first begun with electron bombardment tests. Plotted is the anticipated conservation rate of solar cells, as a function of exposure time. It indicates that the conversion rate of satellite-borne solar cells with no protecting plates will be reduced to approximately 30% of the initial value after one year in orbit, but that it will be possible to keep the rate at not less than 70% if the cells are properly protected by sapphire coatings. It is noted that there may be considerable error in the estimation and in the way of simulating the Van Allen belt, and it should be noticed that the estimation has been made on the assumption that the satellite spends all its time in the Van Allen belt.

257. Harmon, D. and Rasmussen, R.
TEMPERATURE, ILLUMINATION INTENSITY AND DEGRADATION FACTOR EFFECTS ON SOLAR CELL OUTPUT CHARACTERISTICS.
IEEE Transactions on Aerospace and Electronic Systems, AES-2, Suppl.: 78-84, Jly. 1966.

Investigation of a procedure which describes the manipulation of the solar cell I-V curve to account for all factors affecting the output power, except charged particle irradiation damage. The results of empirically derived procedure show excellent agreement with the measured data and find support in theory and in the literature. Comparisons are made with previously used I-V curve shifting techniques, and an example of the complete procedure is given.

258. Harris, D. W. and Epstein, J.
THE INTEGRATION OF RADIOISOTOPE THERMOELECTRIC SYSTEMS AND SPACECRAFT.
New York, Society of Automotive Engineers, 1964, 9p. (Paper 921C.)

Discussion of problems associated with the integration of radioisotope thermoelectric systems and various types of satellites. The effects of the devices upon spacecraft thermal balance, mechanical integrity and configuration, mission interference, and electrical compatibility are explored. Aerospace safety and its dominant role in the practicable use of the devices are considered.

259. Hart, A. B.
FUEL CELLS,
British Interplanetary Society Journal, 19:58-61, May-June 1963.

Fuel cells will be needed in the next decade as primary electric generators of intermediate power, i. e., 100 W. and 10 kW., for spaceflights lasting from a few hours to several days or weeks. Principles of their operation, particularly in relation to the factors and processes which control power yield and heat loss, are discussed. At the present time the most reliable device available is basically a hydrogen/oxygen cell working at 100-200°C. with concentrated potassium hydroxide or an ion exchange resin as the electrolyte. The gases may be carried cryogenically or in chemical form. Brief reference is made to other types of fuel cell.

260. Hart, V. B.
ELECTRICITY FOR SPACE VEHICLES.
New York, American Institute of Electrical Engineers, 1959. n.p.
(Paper CP-59-978.)

Factors such as weight, new sources of electrical energy, long periods of flight, and very large power systems, which contribute to the problem of supplying electricity for space vehicles, are discussed. Research work areas where more effort must be expended are: electric power system design and control, and power conversion.

261. Harteck, P. and Dondes, S.
NEW USES FOR NUCLEAR ENERGY IN OUTER SPACE.
New York, American Astronautical Society, 1967. 13p. (Paper 67-115.)

The use of radioisotopes in small power-generating plants is presented as one method for solving the power-supply problem.

262. Hartman, D. A.
ADAPTIVE POWER CONDITIONING FOR SOLAR CELL ARRAYS.
IEEE Transactions on Aerospace and Electronic Systems, AES-2, Suppl.: 43-47. Nov. 1966.

Technique for the design of power-conditioning equipment which ensures optimal power transfer from a solar-cell array to its load. This new concept, called "adaptive" power conditioning, forces a solar cell to operate at its maximum power point, regardless of its environment, its impedances, or changes in the source volt-ampere characteristics. When load demands decrease, the adaptive feature is automatically disabled and surplus energy remains in the solar array without contributing to satellite overheating or battery overcharging.

263. Hartman, G. F.
ELECTRONIC BATTERIES.
Electronic Equipment Engineer, 6:67-70, illus., Apr. 1958.

Missile batteries trigger take-off devices, fire propulsion fuel, drive blowers and other continuous operations after take-off, energize guidance control circuits and mechanisms, and power telemetering equipment. High power output for weight and size (100 watts to 22 kw) make silver-zinc batteries prime choice.

264. Harvey, D. G., Dick, P. J, and Fink, C. R.
ISOTOPE-GENERATOR RELIABILITY AND SAFETY. II - RADIONUCLIDE POWER FOR SPACE.
Nucleonics, 21:56-59, Apr. 1963.

Demonstration of the reliability and safety of operation of radioisotopic power units for space missions. Operating experience with SNAP power generators indicates that the reliability of the unit is completely satisfactory, and health and safety can be guaranteed against a wide gamut of abnormal circumstances.

265. Harvey, D. G. and Morse, J. G.
RADIONUCLIDE POWER FOR SPACE MISSIONS.
Nucleonics 19:69-72, illus., Apr. 1961.

Concerns the AEC-sponsored SNAP programs of the type which convert heat developed in radioactive decay into electrical energy.

266. Harvey, R. J. and Hatsopoulos, G. N.
ISOTOPIC FUELED THERMIONIC GENERATORS.
In Symposium on Ballistic Missile and Space Technology, 5th, Los Angeles, Calif., Aug. 1960. Proceedings Propulsion and Auxiliary Power Systems, ed., by D. P. LeGalley, p. 409-441, illus., New York, Academic Press, 1960. (Ballistic Missile and Space Technology, vl. 2.)

Progress of the thermionic generator phase in the SNAP-3 program is outlined.

267. Harvey, R. J.
NUCLEAR THERMOELECTRIC POWER SUPPLY.
New York, American Institute of Electrical Engineers, 1959, n.p. (Paper CP 59-911.)

Nuclear power, with its self-contained long-lasting fuel package, its compact design, and capability of high-temperature operation, opens up one of the more promising avenues of inquiry. Direct conversion of nuclear heat to electric power is especially attractive for space vehicles in view of the necessity for long, reliable life. This paper summarizes preliminary work on a thermoelectric space power supply, operating from a reactor heat source. The study, which resulted in a conceptual design, was carried out with reference to a set of specifications describing the more or less ideal space power supply, namely; electrical power output of 2 to 10 kw; no repetitively moving parts or coolant loops; maintenance-free operation

at full power for a minimum of one year; orbital or post-launch startup capability; five-year lead time for development of prototype; and minimum overall weight and size, consistent with the other requirements.

268. Hatsopoulos, G. N.
THERMIONIC ENERGY CONVERSION.
In Intersociety Energy Conversion Engineering Conference, Los Angeles, Calif., September 26-28, 1966, Technical Papers, p. 217-230 New York, American Institute of Aeronautics and Astronautics, 1966.

Summary of the current understanding of the phenomena that take place in a thermionic converter and results of the advances made in thermionic converter performance. The advantages and limitations of thermionic converter are discussed and thermionic systems are reviewed. The basic components of a thermionic converter are a hot electrode (the emitter), a colder electrode (the collector), and two electrically conducting leads that connect each of these electrodes to two power terminals. The basic phenomena in a cesium diode are described as well as the phenomena caused by the presence of cesium in a diode.

269. Haug, W. and others.
ENTWURFSSTUDIE EINER ENERGIEVERSORGUNGSANLAGE FUEL RAUMFLUGGERAETE MIT EINEM THERMISCHEN KERNREAKTOR (TRIKT-50) [DESIGN STUDY OF A NUCLEAR POWER PLANT (TRIKT-50) FOR SPACE FLIGHT].
Atomkern Energie, 10:363-367, Sept.-Oct., 1965. In German.

The specific weight of a nuclear electric power plant for space flight with an electrical output of 50 kW is estimated. The electric energy is obtained by direct conversion of thermal reactor heat by means of thermionic converters. Some pre-established constructive sketches have resulted in a number of data. The plant is described and the approximate masses of the essential components are given.

270. Haviland, R. P. and House, C. M.
HANDBOOK OF SATELLITES AND SPACE VEHICLES.
Princeton, D. Van Nostrand Co., Inc., 1965. 457p.

This handbook is intended to provide a thorough treatment of the subject areas and problems that must be considered during the preliminary stages of satellite or space-vehicle system design. Space power is one of the topics discussed.

271. Hayden, J. T.
AUXILIARY ELECTRICAL SUPPLIES IN SPACE VEHICLES.
World Aviation Electronics, 2:68-72, Feb. 1962.

Methods are enumerated in use and proposed, for generating power for apparatus in satellite and other space vehicles. The methods are compared in terms of the power-to-weight ratio and expected life.

272. Hazard, H. R.
MULTIFUEL THERMAL ENERGY CONVERTERS.
In Power Sources Conference Proceedings, 16th, May 19-21, 1964, p. 124-126, Red Bank, N. J., PSC Publications Committee, 1964.

Portable power sources designed to burn various solid fuels appear feasible and practical. In the 150-watt size range either a Rankine-cycle unit or a thermoelectric unit is attractive. A Stirling-cycle unit appears less attractive, but would be more satisfactory in larger sizes where efficiency would approach 15 percent. Size and weight of solid-fueled power sources will be greater than for liquid-fueled units, and more operator attention will be required.

273. Heacock, R. L.
SCIENTIFIC INSTRUMENTS IN SPACE EXPLORATION.
Science, 142:188-195, Oct. 11, 1963.

General discussion of the principles and techniques of scientific experiments in space. Space systems constraints are discussed, including power, communications, temperature control, and sterilization.

274. HEAT-HAPPY BATTERIES.
Science News, 91:166, 1967.

Long-life silver-zinc batteries for space vehicles, capable of withstanding temperatures up to 100 degrees C., are reported in production at Douglas Aircraft Co., Santa Monica, Calif. Heart of the units is the separator, a device placed between the electrodes to permit ions to travel between electrode compartments, while blocking off the passage of material from the electrodes themselves. The new batteries use separators made of a chemically inert, inorganic material called Astroset, which reportedly will not degrade in very high temperatures, unlike the organic, cellophane-like separators previously used. Intended for space vehicles, satellites and military communications, the batteries have gone through more than 900 discharge-recharge cycles at room temperature and 400 cycles at 100 degrees C.

275. Heath, A. R. Jr. and Hoffman, E. L.
REVIEW OF SOLAR CONCENTRATOR TECHNOLOGY.
In Intersociety Energy Conversion Engineering Conference, Los Angeles, Calif., September 26-28, 1966, Technical Papers, p. 231-237. New York, American Institute of Aeronautics and Astronautics, 1966.

Continuing development of solar concentrator technology has been directed toward the improvement of methods and materials of construction to satisfy the particular design requirements of various space power conversion devices. Descriptions of fabrication-techniques as well as a brief discussion of recent results from investigations made on concentrators are presented.

276. Heins, J. F.
THE DEVELOPMENT OF AN ADVANCED, LIGHTWEIGHT 60 KW ENGINE-GENERATOR SYSTEM.
IEEE Transactions on Aerospace and Electronic Systems, AES-2: Suppl.: 125-129, Jly. 1966.

Description of the construction and performance of a lightweight, high-performance engine-generator system capable of providing reliable, high-quality electric power at a lower mission weight than presently available engine-generator sets. The system is a 60-kw, 120/208- or 240/416-v, 400-cps unit.

277. Henderson, R. E.
DESIGN APPLICATIONS OF DIRECT ENERGY CONVERTERS.
New York, American Society of Mechanical Engineer, 1950, 7p. (Paper 65-MD-50.)

Discussion of devices that convert chemical, nuclear, thermal, or radiative energy directly to electricity without the aid of moving parts. The common source of potential for all these devices arises from the electron theory of solids. Thermionic converters are high-temperature devices for converting thermal energy to electricity. Efficiencies of the order of 10% can be achieved. The thermoelectric converter utilizes semiconductors and in theory can operate at greater than 10% efficiency. The photovoltaic converter converts radiant energy directly to electricity, utilizing silicon and germanium cells. Efficiencies as high as 15% have been observed. Electrochemical converters, solar thermionic converters, radioisotope thermophotovoltaic converters, and electrochemical engines are described.

278. Henderson, R. E. and Bradley, T. G.
POTASSIUM-WATER-OXYGEN FUEL CELL BATTERIES FOR SPACE APPLICATION.
New York, American Society of Mechanical Engineers, 1964, 17 p. (Paper 64 - WA/ENER-3.)

Description of an alkali-metal fuel cell, the system of components required to sustain its operation, and the weight optimization of this system for two space applications. The concept is that of a combined liquid-metal cell and an air-amalgam cell. The liquid metal cell develops electrical energy by reacting K and Hg to form a potassium amalgam. The air-amalgam cell takes potassium from the amalgam to combine with oxygen and water to make KOH. Thus, potassium, water, and oxygen must be stored as reactants, with KOH.being the product of the reaction. System components required include a radiator to remove excess heat from the electrolyte efflux, storage for KOH added by the cell, and heat exchangers and pumps. An energy analysis is presented which accounts for all major energy transfers, both electrical and thermal, to ascertain the attendant

levels of availability. It is shown that manipulating certain primary factors leads to minimum weight for electrochemical power sources. Two systems are compared: (1) an orbital power supply where the electrochemical device is used to store electrical power developed by a set of solar cells, and (2) a lunar power unit for use in a mobile vehicle which must be recharged or refuelled upon return to a central depot.

279. Henderson, R. E. and Dresser, D. L.
THERMIONIC CONVERTERS FOR SPACE POWER SYSTEMS.
Society Automotive Engineers Journal, 69:72-77, illus., Aug. 1961.

Two types of thermionic converters are being considered for solar thermionic systems to provide electrical power for space vehicles: the vacuum diode and the vapor diode. To illustrate the application of both these types, two systems are described. The first illustrates the use of the vacuum diode in a system for a low orbit satellite mission. In the second, the vapor diode is used in a system designed as a Mars space probe. Based on SAE Paper 350C.

280. Hernquist, K. G.
ROCKET'S EXHAUST HEAT IS TURNED TO ELECTRIC POWER; THERMIONIC GENERATOR.
Electrical Engineering, 79:170, illus., Feb. 1960.

Also in Franklin Institute Journal, 269:155-156, Feb. 1960, and American Society of Naval Engineers Journal, 72:108, Feb. 1960 with slightly different titles. They represent RCA press releases.

281. HIGH VOLTAGE DERIVED FROM HEAT SOURCES.
Electronic Industries, 19:7, Jan. 1960.

Refers, briefly, to a new device, announced by International Telephone and Telegraph Co., that can produce high-voltage electricity directly from the warming power of a sunbeam or other heat source. Called a ferroelectric converter, the device may have far-reaching effects in space communications and space travel.

282. Hirsch, R. L. and Holland, J. W.
PROBLEMS ASSOCIATED WITH THE DEVELOPMENT OF A THERMIONIC CONVERSION REACTOR.
Paper presented at the ARS Space Power Systems Conference, Santa Monica, Calif., Sept. 27-30, 1960. New York, American Rocket Society, 1960. 12p. (Paper 1338-60.)

A conceptual design of a 300 kw(e) thermionic space power reactor is described with a subsequent discussion of associated development requirements. The thermionic converter is integrated into the nuclear reactor core in such a manner that the fuel material also serves as the cathode of the converter. The thermionic fuel elements are assembled into a close spaced hexagonal lattice to form a 0-in. in

diameter by 10-in. long cylindrical reactor core. Assumptions of converter performance are based on a reasonable extrapolation of current experimental data. The requirements that exist for all materials within the thermionic cells include high temperature capability, physical and chemical compatibility, fabricability, and joinability, and ability to withstand thermal cycling and a high radiation environment. The techniques for increasing core performance by thermionic converters are discussed.

283. Hittman, F. and Silverstein, C. C.
RADIOISOTOPE-FUELED THERMOELECTRIC GENERATORS.
In Engineering Developments in Energy Conversion; International Conference on Energetics, University of Rochester, Rochester, N. Y., August 18-20, 1965, Proceedings, p. 156-173. New York, American Society of Mechanical Engineers, 1965.

Discussion of the possibilities of advantageous use of radioisotope-fueled thermoelectric generators (RTG) in both space and terrestrial applications where long life and reliability are important. It is noted that, for space applications, thermoelectric generators are particularly attractive for missions requiring tens to hundreds of watts of electrical energy for extended periods. In addition, for space missions of long duration, where a source of solar energy cannot be used, they may be today the only practical way of generating the required amounts of power. In terrestrial applications, where long life, freedom from the logistics of refueling and dependability of operation are required, RTGs also appear to have a promising future.

284. Hoffman, B. and Shair, F.
THE APPLICATION OF ALKALI METAL VAPOR SYSTEMS TO MHD SPACE POWER GENERATORS.
In Proceedings of 1963 High-Temperature Liquid-Metal Heat Transfer Technology Meeting. Oak Ridge National Laboratory, September 4-6, 1963, p. 316-352. 1964. (ORNL-3605, vl. 2.)

This report describes a theoretical and applied research program directed toward prolonging the lifetime of magnetohydrodynamic (MHD) energy converters by reducing the necessary operating temperatures to the range 1000^{o} - 2000^{o}K. The process of interest is the use of the magnetically induced electric field in the MHD generator for electrical breakdown of appropriate working fluids. Work was directed toward the use of alkali metals for Rankine (vapor) cycles (although the results are applicable to Brayton cycles with certain nuclear reactors) and alkali metal seeded noble gases for studying the basic parameters of the breakdown.

285. Holechek, J. J.
CHEMICAL HEATING FOR MISSILE BATTERIES.
In Power Sources Conference. Proceedings, 15th, 1961, p. 89-92, figs., Red Bank, N. J., PSC Publications Committee, 1961.

Some of the activation devices developed for general application to the zinc-silver oxide primary battery are indicated. Investigation, thus far, has furnished proof that chemical heat and heat exchanger devices are feasible.

286. Hottel, H. C. and Erway, D. D.
COLLECTION OF SOLAR ENERGY.
In Introduction to the Utilization of Solar Energy, p. 86-106, McGraw-Hill Book Co., New York, 1963.

Description of the principles of operation of flat-plate solar energy collectors. Data are presented on the typical performances of these collectors, and design methods and equations are given. Some applications of flat-plate collectors in space power systems are briefly considered, and it is noted that they are noncompetitive with other potential power systems because of their unfavorable specific weight.

287. Houck, O. K. and Heath, A. R., Jr.
CHARACTERISTICS OF SOLAR CONCENTRATORS AS APPLIED TO SPACE POWER SYSTEMS.
New York, Society of Automotive Engineers, 1964. 34p. (Paper 867C.)

An analysis is presented of current solar concentrator types when integrated into complete space power systems with various electrical conversion methods. Concentrator designs such as inflatable-rigidized, petal, one-piece, and Fresnel are treated in the paper and their size, weight, and packaging characteristics, when combined with dynamic and static conversion schemes, are illustrated. Information presented in the paper provides insight into the selection of concentrator designs for space power applications.

288. Houston, J. M.
A SURVEY OF THERMIONIC CONVERSION FOR SPACE POWER.
In Nerem Record 1965; Northeast Electronics Research and Engineering Meeting, Boston, Mass., November 3-5, 1965, Papers. vl. 7, p. 144, 145. Boston, Institute of Electrical and Electronics Engineers, Boston Section, 1965.

Evaluation of the thermionic converter, a device which converts heat into electrical energy by using the thermionic emission of electrons. The motive diagram and current-voltage characteristics are given for an ideal converter, and values are plotted which show how maximum efficiency and power at maximum efficiency vary with emitter temperature for two emitter-collector spacings. A cutaway drawing is given of a solar-thermionic converter developed by Thermo Electron Engineering Corporation, and an idealized cross section of a nuclear thermionic fuel rod is shown.

289. Houston, J. M. and Webster, H. F.
THERMIONIC ENERGY CONVERSION.
In Advances in Electronics and Electron Physics, vl. 17:125-206, New York, Academic Press, 1962.

This paper surveys the state of thermionic converters. These devices convert heat energy into electrical energy by utilizing the thermionic emission of electrons. The power output and efficiency of such devices have reached around 5 watt/cm^2 at 15% efficiency.

290. Howard, H. J. and Laughlin, R. M.
THE USE OF CHEMICAL POWER SYSTEMS IN THE CONSTRUCTION, SERVICING AND OPERATION OF MANNED SPACE STATIONS.
In Proceedings of the Manned Space Stations Symposium, Los Angeles, 1960, p. 254-258, New York, Institute of the Aeronautical Sciences, 1960.

Systems using chemical fuels will be needed to supply electrical and hydraulic power in the space station support vehicles and for standby power on the space station itself. It is hypothesized that the open cycle hydrogen-oxygen system, which stores hydrogen in its liquid state, is the lightest, and has several advantages and benefits, would be the best for the space ferry.

Also in Aero/Space Engineering, 19:62-63, May 1960.

291. Howard, P. L.
NEW DEVELOPMENTS ARE IMPROVING PERFORMANCE OF SILVER-ZINC BATTERIES.
Electronic Industries, 17:61-63, illus., Jly. 1958.

Developments, materials, and techniques that offer the most promising prospects for this powerful cell are presented. Some of the more prominent applications are mentioned, including missiles and rockets.

292. Howard, P. L.
THE SEALED SILVER-CADMIUM BATTERY.
Electrochemical Technology, 1:272-276, Sept.-Oct. 1963.

Requirements for 90- to 100-min cycles of a 30- to 40-min discharge and a 60- to 70-min recharge necessitated the development of a new design: a sealed silver-cadmium battery which could be recharged during this period. A report of this development and on cycling results is given here. Over 7000 cycles have been obtained at 50%-capacity discharge a 100-min cycle of 35 min of discharge and 65 min of recharge. A discussion of charging characteristics and voltage is given. This system makes it possible to achieve a sizable decrease in the weight and volume of a battery to be used in a satellite regime.

293. Howard, P. L.
THE SILVER-ZINC RECHARGEABLE BATTERY.
Institute of Radio Engineers Convention Record 4(Part 6, Manufacturing Electronics):132-136, illus., 1956.

Describes the characteristics, operation and applications of the Yardney Silvercel battery designed to solve power requirements where space and weight are important.

294. Howard, R. C. and Rasor, N. S.
NUCLEAR THERMIONIC SPACE POWER SYSTEMS.
From 18th Annual IAS Propulsion Meeting, Cleveland, Mar. 1963. 62p.

The various concepts for utilizing thermionic conversion in space reactor power plants are described and evaluated.

295. Howard, R. C.
THERMIONIC REACTOR SYSTEMS.
American Nuclear Society Transactions, 3:383, Dec. 1960.

Indicates three basic approaches to incorporating thermionic cells into reactor systems for use as space, marine, and central station power plants.

Article with same title appears in Nuclear Science and Engineering 10:173-182, June 1961.

296. Howson, R. P., Roberts, D. H. and Wilson, B. L. H.
SOME THERMAL CONSIDERATIONS ON THE USE OF SOLAR CELLS.
British Institute of Radio Engineers Journal, 22:519-525, figs., Dec. 1961.

The dependence of solar cell characteristics on temperature is demonstrated. The radiation balance of solar cells in space is then discussed for different configurations of the cell assembly and for different orbits and it is shown that these can have considerable influence. Means of achieving temperature stabilization are described. The value of surface coatings is discussed briefly.

297. Huffman, F. N.
CONCEPTUAL DESIGN OF A THERMIONIC SPACE POWER PLANT.
New York, American Institute of Electrical Engineers, 1959. n.p.
(Paper CP 59-910.)

The current search for a reliable and simple space vehicle power plant has stimulated studies of thermoelectric, photoelectric and thermionic schemes for the direct conversion of heat to electricity without rotating parts. Treated here in elementary fashion are the basic principles of thermionic conversion, and a conceptual design is presented for a 25-kw space power plant subject to the constraint of no repetitive moving parts.

298. Hughes, W. L., Summers, C. S. and Allison, H. J.
AN ENERGY SYSTEM FOR THE FUTURE.
Institute of Electrical and Electronic Engineers Transactions, IE-10: 108-111, May 1963.

A technique for the practical utilization of solar energy on a continuous basis to provide bulk power is described. The output

of solar energy converters is used to produce hydrogen by pressure electrolysis of water. The energy stored in the hydrogen can be efficiently transformed into electrical energy by the use of hydrogen-oxygen fuel cells.

299. Hunrath, G.
APPLICATION OF SOLAR ENERGY.
In Battery Research and Development Conference, 11th, 1957, p. 99-102, illus., Fort Monmouth, N. J., U. S. Army Signal Engineering Laboratories, 1957.

Results of rocket experiments at White Sands Proving Ground indicate that it is possible to design a solar energy conversion system capable of furnishing power on a long term basis for the various satellite instrumentation, and thereby increase the value of the data obtained from the various experiments that will be made.

300. Hunrath, G.
SOLAR POWER SUPPLIES FOR GROUND USE.
In Power Sources Conference Proceedings, 17th, 1963, p. 8-11. Red Bank, N.J., PSC Publications Committee, 1963.

The program at the U.S. Army Electronics R&D Laboratory, covering the conversion of solar energy into electrical power is directed toward investigating system feasibility for military ground applications. Various designs of solar photovoltaic energy converters are described.

301. Hunrath, G.
SOLID STATE POWER SUPPLIES.
Control Engineering, 8:173-177, illus., Sept. 1961.

Silicon photovoltaic cells and thermocouples can convert solar energy and heat into electrical energy. Both means of energy conversion are potential self-contained power supplies for control and data handling systems. Prime applications have been in satellites and other inaccessible military systems, but isolated examples of industrial use already exist. Device characteristics such as capacity, efficiency, and weight, and system considerations are covered to acquaint control engineers with this new solution to the remote power supply problem.

302. Hunter, G. S.
CELL STUDIES SPUR SOLAR POWER ADVANCES.
Aviation Week and Space Technology, 87:94-107. 1967.

Investigations by various companies and government laboratories into the basic efficiency of the solar cell are delineated. "Among the anticipated advances are better understanding of the fundamental

processes in the energy conversion mechanism of the cell, leading to: more adaptive, stable and diversified cell configurations; improved fabrication methods involving new cell materials, film deposition techniques and bonding media."

303. Huth, J. H.
ASPECTS OF MAGNETOHYDRODYNAMIC (MHD) GENERATOR FOR SPACE.
Paper presented at the ARS Space Power Systems Conference, Santa Monica, Calif., Sept. 27-30, 1960. New York, American Rocket Society, 1960, n.p. (Paper 1320-60.)

This paper discusses the general characteristics, problems, and work in progress on magnetohydrodynamic (MHD) electrical-power generators. It is concluded that MHD generators will initially find their main application as a source of short-duration large power pulses.

304. Huth, J. H.
DIRECT POWER CONVERSION - PART 1.
In Alperin, M. and G. P. Sutton, eds. Proceedings of Advanced Propulsion Systems Symposium, Los Angeles, 1957, p. 145-149. New York, Symposium Publications Division, Pergamon Press, 1959. (International Series on Aeronautical Sciences and Space Flight, Symposia, vl. 2.)

This paper reviews some of the motivations for interest in direct power conversion from the point of view of providing energy for space vehicles. A brief review of the many proposed direct-conversion devices is given, including solar cells, fuel cells, and thermocouples.

305. Huth, J. H.
ELECTRICAL POWER FROM ROCKETS.
Paper presented at the Semi-Annual Meeting of the American Rocket Society, Los Angeles, May 9-12, 1960. New York, American Rocket Society, 1960, 14p. (Preprint 1147-60.)

The characteristics of magnetohydrodynamic generators, as applied to ground-base chemical-rocket exhausts, are discussed. Simple open-cycle units can have ultimate efficiencies up to 40%, and can provide electrical power on very short notice. More specifically, rocket-powered MHD generators are suited to applications requiring hundreds or thousands of electrical megawatts for a few minutes. Within this range power densities (including the magnet) of at least 250 kw/ft^3 can be foreseen. The main problems center about developing suitable materials for operation near 2000 to 3000°K. No moving parts are required in the MHD generator, where these temperatures manifest themselves.

306. Huth, J. H.
POWER SUPPLIES FOR ORBITAL AND SPACE VEHICLES.
In Ordway, F. I. III, ed., Advances in Space Science, p. 11-157, New York, Academic Press. 1959.

A discussion of power sources for space which touches on the following topics: environmental conditions which may affect the performance of power sources, power demands, primary sources of power, conversion techniques, and problems of joining various components into a complete system. A bibliography of 84 reference is appended.

307. Huth, J. H.
WHAT POWER SOURCES IN SPACE?
Astronautics, 3:24-25, 62-64, illus., Oct. 1958.

Forecasts use of certain oxidic materials such as ferrites and titanates which may exhibit desirable thermoelectric properties at temperatures as high as 600-1000°C.

308. HYDROCARBON FUEL CELL.
Engineer, 215:1055-1058, June 7, 1963.

The General Electric Company, presented the first public demonstration of a new type of fuel cell, which operates on a wide variety of common hydrocarbon fuels, including ordinary diesel oil. Fuel cells, convert chemical energy directly into electrical energy. They use common fuels and oxygen, but without combustion or moving parts. Because the fuel cell does not employ a heat cycle, the efficiency is inherently more than twice that of the best conventional power generators. Of all the several so-called "unique" energy conversion methods principally useful as portable power sources, the firm is most optimistic about fuel cells, and a large number of space, military and marine uses await their further development.

309. Iles, P. A.
APPLICATIONS OF SOLAR CELLS IN SPACE TECHNOLOGY.
In Nomura, T. ed., International Symposium on Space Technology and Science, Tokyo, Japan, August 27-31, 1962, 4th, Proceedings, p. 711-717. Tokyo, Japan and Rutland, Vt., Japan Publications Trading Co., 1963.

Discussion of solar cells which have been used as secondary power source for reasonably long periods (over a month) by most satellites and space probes. Solar cell properties are summarized in order to examine how cell performance may be affected by rocket launching conditions or by the operating environment in orbit. A survey is also provided of the fashion in which the design of solar cells and of arrays of cells has enabled successful operation under these conditions. An outline is also furnished of some of the present research work aimed at still better performance. Briefly examined are some of the present developments which should provide the framework for improved solar cell power supply design in the near future. In conclusion, it is reviewed how solar cell power supplies have proved satisfactory and reliable for many secondary power needs, and

how there is still hope for improved performance. The power provided has increased by a factor of 10^4, and some plans envisage provision of more than 10 kw. It is noted that, because of the proved performance of solar cells, solar power should continue to be converted with photovoltaic cells in many future satellites and, perhaps, on small planetary exploring vehicles.

310. IMPROVED BATTERY MEETS OUTER SPACE REQUIREMENTS.
Electronics 34:110, 112, illus., Jan. 13, 1961.

Gives details of a rechargeable nickel-cadmium battery with a true hermetic seal. It may be used in conjunction with solar cells as a power source in satellites.

311. Ingling, W. G. and Clark, W. W.
EVALUATION OF SECONDARY BATTERIES.
In Power Sources Conf., Proceedings, 17th, 1963, p. 122-124, Red Bank, N. J., PSC Publications Committee, 1963.

Final results in terms of cycle life for each of 10-cell groups and batteries are given.

312. Inman, B. D.
THERMAL GENERATION OF ELECTRICITY AND THERMOELECTRIC HEAT PUMPS.
Armed Forces Chemical Journal, 13:20-21, Nov/Dec. 1959.

This is a brief resume of the Navy's thermoelectricity program and a forecast of important special purpose military applications for thermal electricity.

313. Ioffe, A. F.
THERMOELECTRIC AND THERMAL PROPERTIES OF SEMICONDUCTORS.
Journal de Physique et de Radium, 18:209-213, Apr. 1957.

Discussion with reference to the application of semiconductor thermocouples for power supply.

314. ION-MEMBRANE FUEL CELL PASSES TEST FOR SPACE USE.
Electronic Design, 10:48, Mar. 15, 1962.

The cell is powered by hydrazine mixed with nitric acid.

315. Isaacs, H. H.
SYSTEM ENGINEERING AND DECISION THEORY TECHNIQUES FOR THE SELECTION OF ROCKET POWERPLANTS.
Fusees, 22:32-39, 1963.

Discussion of a concept of decision making, examining the problem of initial selection of a rocket powerplant for a new application. The characteristics and methodology of Operations Research are

reviewed and related to System Engineering, System Analysis, and System Design. The process of powerplant selection for a given application is described. Methods of decision making relating to this problem are explored. Factors of comparison are listed, and means of evaluating non-specifics are discussed.

316. Jackson, W. D.
MAGNETOHYDRODYNAMIC POWER GENERATION - A STATUS REPORT.
Electronics and Power, 10:258-263, Aug. 1964.

Description of the historic and theoretical background of the development of magnetohydrodynamic (MHD) power generation, and a survey of promising recent applications, such as topping devices and space vehicle power systems. It is stated that MHD power generation has now progressed to the point where several applications are receiving detailed attention and others are in prospect. Electrical power generation onboard both surface vessels and submarines may be achieved using modified versions of space-vehicle systems, and high-power, short-duration power generation seems especially suited to MHD machines.

317. Jackson, W. D.
PLASMA-MHD POWER GENERATION.
In Nerem Record 1965; Northeast Electronics Research and Engineering Meeting, Boston, Mass., November 3-5, 1965, Papers. vl. 7, p. 138, 139. Boston, Institute of Electrical and Electronics Engineers, Boston Section, 1965.

Discussion of MHD nuclear-electric space power systems which use noble gases seeded with small amounts of alkali metal vapors as the working fluid. The high-temperature working fluid is expanded to a velocity of about 300 m/sec in the isentropic process. The high-velocity flow is adiabatically diffused at the generator exit to eliminate frictional dissipation and to minimize compressor work. Cooling occurs by radiation to space. The working fluid is adiabatically compressed and heat is added by a gas-cooled nuclear reactor to return the working fluid to its initial state. The plasma-MHD power generation cycle retains the potential advantages of an all-gas system for space applications and offers high-temperature operation without turbo machinery.

318. Jasinski, R. J. and Kirkland, T. G.
FUEL CELLS - A STATE-OF-THE-ART REPORT. I.
Mechanical Engineering, 86:51-57, Mar. 1964.

Discussion and evaluation of individual fuel cells for conversion of chemical energy to low-voltage direct-current electricity. Classification by fuel is considered definitive, the fuels being non-hydrocarbons, hydrocarbons, reformed fuels, and specialty fuels. Cell configuration and technology are primarily controlled by the

fuel factor. Power density, power-weight ratios, and electrode size are major parameters for evaluation of performance. Six hydrogen/oxygen fuel cells are described, and this is considered to be the simplest and hence most advanced cell. Sodium-amalgam/-oxygen, ammonia, and hydrazine cells are outlined, with the note that the hydrazine cell is, from the engineering viewpoint, as advanced as the hydrogen cell. Hydrocarbon fuels including alcohols are considered, with the observation that these may have an early commercial applicability. Hydrocarbons may be utilized in reformed fuels by converting them to more reactive materials. Solar energy may be used to regenerate reaction products. Biochemical energy from microorganisms may be direct or indirect, probably the latter. Zinc/oxygen fuel cells have produced a current density of 75 amp/-sq ft with a cell voltage of 0.9 volt.

319. Jasinski, R.
HIGH-ENERGY BATTERIES.
New York, Plenum Press, Division of Plenum Publishing Corp., 1967. 326 p.

A summary of the basic principles and technology of battery performance, emphasizing high-energy batteries, is given in this text. Surveyed information covers the time period from 1945 to the present. Within the context of this volume the term high-energy battery applies to a minimum energy density of at least 100 watt-hr/lb for primary batteries and 50 watt-hr/lb for secondary batteries.

320. Jenny, E.
SURVEY OF THE FOUR MOST IMPORTANT PROCESSES FOR THE DIRECT CONVERSION OF ENERGY (HEAT INTO ELECTRICITY).
Bulletin de Societe Royale Belge Electrique, 78:227-248, Jly.-Sept. 1962.
In French.

This survey considers methods based on chemical cells, thermoelectricity, thermionic generators, and magnetohydrodynamic generators. In each case, the principles and the practical designs and developments are described.

321. Johnson, K. P.
DYNAMIC VERSUS DIRECT CONVERSION.
Paper presented at the ARS Space Power Systems Conference, Santa Monica, Calif., Sept. 27-30, 1960. 27 p., New York, American Rocket Society, 1960. (Paper 1321-60.)

The performance capabilities of advanced nuclear dynamic and nuclear direct conversion space electric power plants are compared on a lb/kw basis.

322. Johnson, K. P.
SECONDARY NUCLEAR POWER PLANTS.
Space/Aeronautics, 37:71-74, illus., Apr. 1962.

Reviews present state of the art and future systems for providing nuclear electric power for space vehicles. Emphasizes the need for higher radiator temperatures to make possible power units capable of delivering levels over 510 kw.

323. Johnson, R. A., Morgan, W. T. and Rocklin, S. R.
DESIGN, GROUND TEST AND FLIGHT TEST OF SNAP 10A, FIRST REACTOR IN SPACE.
Nuclear Engineering and Design, 5:7-21, Jan.-Feb. 1967.

Discussion of the reactor-thermoelectric system and development program that preceded the flight of SNAP 10A, the first nuclear-reactor space power system. The endurance test experience gained from the nuclear ground test system is emphasized, and the flight test is described. The nuclear ground test demonstrated a capability of starting on a single command and operating for 10,000 hr unattended. A consistency of operation was demonstrated which assures that reactor thermoelectric systems can be designed for operation with passive control - i. e., with the control system deactivated after a short initial control period.

324. Jones, K.
SECONDARY POWER IN ADVANCED FLIGHT VEHICLES.
Aero/Space Engineering, 18:54-57, 63, Aug. 1959.

Systems are defined here as all electric, hydraulic, and pneumatic power required to operate subsystems. The principal requirements for national, military, or scientific exploratory systems are reviewed. Systems discussed include: total secondary power required; possible sources of power, including atomic and chemical batteries, solar cells, thermionic converters, thermopile generators, fuel cells, atomic power units (isotope and reactor), and magnetohydrodynamics. A quantitative definition of hyperenvironments for electrical systems is also tabulated.

325. Jones, R. A. and Keeler, J. S.
FLIGHT VEHICLE POWER.
New York, Society of Automotive Engineers, 1959. 9p. (Preprint 105U.)

The requirements of space power systems for the following purposes are first considered: boost glide vehicle power, short duration satellite (auxiliary) power, electrical thrust power, long duration satellite (auxiliary) power. The way in which these requirements may be met by the following energy conversion systems is then discussed: batteries, fuel cells, chemical dynamic systems, nuclear power systems, and solar power systems.

326. Jones, R. A. and Keeler, J. S.
BETTER ENERGY CONVERSION DEVICES ARE NEEDED.
Society of Automotive Engineers Journal, 68:30-33, Jan. 1960.

Major conversion devices discussed are batteries, fuel cells, chemical dynamic systems, nuclear power system and static solar systems.

327. Kammpermann, H.
CATHODIC PROTECTION AGAINST CORROSION AND THE APPLICATION OF ISOTOPE BATTERIES.
In Industrial Applications for Isotopic Power Generators, p. 191-193, Paris, European Nuclear Energy Agency, 1967.

Electric power supply requirements are assessed, with particular reference to cost of supply, and power supply problems in remote areas considered. Examples of apparatus and protection systems are given.

328. Kantrowitz, A.
POWER IN THE SPACE AGE.
Astronautics, 6:54-55, 118-119, Oct. 1961.

The article indicates in what way the current enthusiasm for magnetohydrodynamics stems from close relationship both to nuclear energy and space flight.

329. Kantorwitz, A. and Brogan, T.
VERY HIGH POWER, LIMITED DUTY CYCLE, ROCKET DRIVEN MHD GENERATORS.
In Proceedings of the IDA Pulse-Power Conf., February 4-5, 1963, p. 132-162. Washington, D. C. Institute for Defense Analysis, 1963. (S-104)

With the use of an MHD generator the heat released in the combustion chamber of a rocket engine can be converted to electric power at an efficiency approaching that of a complete utility plant, while preserving advantages in weight, cost, and size.

330. Kaye, S., Weiman, I. and Wright, W. V.
A NEW RADIATION DAMAGE RESISTANT SOLAR CELL.
New York, American Rocket Society, 1962. 24 p. (Paper 2567-62.)

The design and performance of an experimental silicon p-n junction solar cell intended for space application is described.

331. Kelly, C.
FLIGHT VEHICLE POWER FORECASTS.
In Snyder, N. W. ed., Space Power Systems, p. 625-632, illus., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 4.)

Forecasts of optimum application of energy conversion methods are presented and described. Comment is offered on the more significant problems and intriguing aspects of certain specific energy conversion methods.

332. Kemp, B.
WHAT MAKES GUIDED MISSILES TICK?
New York, American Electronics Co., 1958, 95 p.

In the chapter about missile electronics (pp. 55-62), solar batteries, thermocouples, radioactive batteries, and nuclear fission generators of missile are described, discussed, and diagramed.

333. Kennerud, K. L.
ELECTRICAL CHARACTERISTICS OF SILICON SOLAR CELLS AT LOW TEMPERATURES.
IEEE Transactions on Aerospace and Electronic Systems, AES-3:586-590, Jly. 1967.

Experimentally determined values of open-circuit voltage, short-circuit current, and maximum power for p on n and n on p silicon solar cells are presented.

334. Kerr, D. L. and Gessner, R. L.
MINIMIZING THE WEIGHT OF THERMOELECTRIC GENERATORS IN SPACE APPLICATIONS.
New York, American Institute of Electrical and Electronic Engineers, 1959. n.p. (Paper CP 59-937.)

The importance of reliability and weight as performance criteria for equipment to be used in space vehicles is stated. The inherent potential advantage of a thermoelectric generator and other static devices from the standpoint of reliability is pointed out. The need is indicated for making weight estimates of thermoelectric generator systems on a consistent basis for purposes of evaluation and direction of future work. A thermoelectric generator system for providing auxiliary power for space vehicles is defined, and some discussion is given of the role of efficiency in weight minimization. Finally, an approach for predicting and minimizing the weight of a thermoelectric generator is briefly outlined and results of a number of calculations using this procedure are presented.

Also in Egli, P. H., ed. Thermoelectricity, p. 47-74, illus., New York, Wiley, 1960.

335. Kerr, D. L.
THERMOELECTRIC ELEMENTS IN SPACE POWER SYSTEMS.
In Snyder, N. W., ed., Energy Conversion for Space Power, p. 85-109, illus., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 3.)

A discussion is presented of some of the characteristics, potentialities, and problems encountered in the design of thermoelectric generators for space applications. One means of classifying the basic configurations possible is according to the means of rejecting heat from the cold junction, i. e., whether it be to a secondary heat transfer fluid which in turn passes through the radiator or

whether the generator waste heat is carried directly to the radiating surfaces by thermal conduction from the cold junctions. Presented are results of some studies which have been made of the latter case where the generator is integral with the radiator. Two types of construction have been investigated which can be termed the "sandwich" type and the "side fin" type. Estimates of the minimum weight obtainable from each are presented for particular materials properties. Comparison of these indicates that a combination of the two types of construction will result in the least weight.

336. Kerr, R. L.
FUEL CELL ORBITAL EXPERIMENT.
IEEE Transactions on Aerospace, AS-2:789-799, Apr. 1964.

The design, experimental fabrication and environmental evaluation of a capillary-type hydrogen-oxygen fuel cell have recently been completed. This unit is the first of several fuel cells to be developed as electrical power sources for extraterrestrial applications.

337. Kershaw, W. L.
RADIOISOTOPE POWER SOURCES.
In Power Sources Conference, Proceedings, 16th, 1962, p. 64-67, Red Bank, N. J., PSC Publications Committee, 1962.

Radioisotope fueled thermoelectric generators have proved to be practical devices for use in remote locations.

338. Kessler, J. R.
HYPERGOLIC FUELED RECIPROCATING SPACE POWER UNIT.
New York, American Institute of Aeronautics and Astronautics, Sep. 1964, 8 p. (Paper 64-755.)

Description of a hypergolic, Space Power Unit (SPU), designed and built for the NASA Manned Spacecraft Center, It is stated that the SPU concept holds promise of being an attractive, practical solution to some of the electrical power generation needs currently foreseen for future manned and unmanned exploration of space. The concept embodies design features which provide high reliability, economy, long life, and simplicity of design and ease of maintenance. It is noted that integration of the total system into other space vehicle or planetary base required subsystems should be straightforward and readily achieved. All investigations conducted to date point to the complete feasibility and future potential of the concept.

339. Kilbon, K.
ENERGY CONVERSION.
Radiotronics, 28:3-7, Jan. 1963.

New electronic technology, founded upon pains-taking research, is preparing a future era of noiseless generators that function without moving parts to transform heat, light, and chemical energy directly and simply to abundant electric power - first in handy packages for use anywhere on earth or in space, and eventually in great central stations serving urban industrial complexes across the continent.

340. Kipp, E. W., Schlotter, W. J. and Cahill, J. E.
APPLICATION OF BATTERY POWER SUPPLIES IN RE-ENTRY AND RECOVERY VEHICLES.
American Rocket Society Space Power Systems Conf., Sept. 25-28, 1962. Santa Monica, Calif., 1962. n.p. (Paper 2507-62.)

Behavior of batteries is reported.

341. Kirkland, T. J. and Jasinski, R.
FUEL CELLS - STATE OF THE ART.
Institute of Electrical and Electronic Engineers Transaction, IE-10: 112-124, May 1963.

The current intensive effort on fuel cell research and development is justified by the potential uses and advantages. Many industrial laboratories are investigating some form of mobile power in which high efficiency, low manufacturing cost, and low maintenance are the most important factors. Another potential large application for fuel cells and the one that is receiving the most attention at this time is in aerospace vehicles where this form of power satisfies many special needs.

342. Kittl, E.
THERMAL ENERGY CONVERSION.
In Battery Research Conference. Proceedings, 12th, p. 113-115, Fort Monmouth, N. J., U. S. Army Signal Research & Development Laboratory, Power Sources Division, 1958.

Relates the thermal energy conversion aspects of solar and nuclear forms of energy.

343. Klass, P. J.
ARPA STUDIES AUXILIARY SPACE POWER.
Aviation Week, 71:89-91, 93, 95, 97, Jly. 13, 1959.

Briefly lists some of the industrial concerns actively investigating means for generating electric power, and describes their objectives. The article also indicates some of the more promising possibilities for electric power systems for space vehicles, among them the solar thermoelectric system, solar thermionic system, and the nuclear thermoelectric system.

344. Klass, P. J.
SOLAR ENERGY COULD DRIVE SPACESHIP'S ELECTROSTATIC POWER DRIVE, IRE HEARS.
Aviation Week, 62:76-82, illus., Apr. 25, 1955.

An electrostatic power plant fueled by the sun's energy may power spaceships, according to Dr. Ernst Stuhlinger, ex-German rocket scientist. The ship would carry 40 or more large parabolic reflectors for converting solar energy into electric power.

345. Klass, P. J.
THIN-FILM SOLAR CELLS BOOST OUTPUT RATIO.
Aviation Week & Space Technology; 83:67-70, Nov. 29, 1965.

New types of lightweight polycrystalline solar cells made from materials other than long-used silicon promise a ten-fold increase in output-to-weight ratio, thereby opening up new space power options.

346. Klem, R. L. and Dingwall, A. G. F.
SILICON-GERMANIUM THERMOELECTRIC POWER-GENERATING DEVICES.
In Engineering Developments in Energy Conversion; International Conference on Energetics, University of Rochester, Rochester, N. Y., August 18-20, 1965, Proceedings, p. 141-155. New York, American Society of Mechanical Engineers, 1965.

Evaluation of the progress in work on silicon-germanium (SiGe) thermoelectric alloy power sources. The principles of thermoelectric energy conversion are reviewed and the efficiency of SiGe and other thermoelectric alloys is assessed. The mechanical and chemical characteristics of SiGe alloys described include high melting point, unprotected operation in air and vacuum environments, low vapor pressure, improved strength, low weight, low coefficient of thermal expansion, advanced contacting technology, and high figure-of-merit. The SNAP 10A power system is given as an example of the use of SiGe for space applications. The Soviet "Romashka" thermoelectric system and the RCA developed "Air-Vac" thermocouple construction are described.

347. Klem, R. L.
THERMOELECTRIC ENERGY CONVERSION.
Signal, 18:52-56, Aug. 1964.

Discussion of the theoretical fundamentals and practical applications of thermoelectricity with emphasis on the latest high-efficiency silicon-germanium thermoelectric power generators using relatively straightforward construction techniques. The SNAP-10A nuclear-reactor system using a thermoelectric converter, and the SNAP-17A radioisotope-thermoelectric system, designed for space use, and applying strontium 90 as the thermal-energy source, are

described in detail. Thermoelectric generators using fossil-fuels heat sources are briefly surveyed. The ability of silicon-germanium thermoelectric material and the associated structures to operate successfully without protection in the combustion gases of fossil fuels is indicated.

348. Klem, R. L. and Helwig, W. J.
THERMOELECTRIC TECHNOLOGY FOR SPACE-POWER SYSTEMS.
New York, American Institute of Aeronautics and Astronautics, 1965, 8 p.
(Paper 65-469.)

Description of design considerations and performance data for silicon-germanium thermoelectric converters which can be used in nuclear applications (such as SNAP 10A) with either reactor or isotope heat sources. As an alternative to increasing the heat rejection at the cost of increased radiator weight, raising the source temperature provides a means of increasing the temperature drop across the thermoelectric materials and thus increasing the conversion efficiency. The new Si-Ge thermoelectric alloys have such physical and electrical properties that temperature limitations are usually imposed by other factors in the system rather than by the material. Coupling of heat from a nuclear source to the actual conversion system by means of a liquid-metal loop is discussed, as well as the "air-vac" thermocouple configuration for radiation-type coupling. Si-Ge thermoelectric modules can withstand launch and space operational environments. They have exhibited stable operation over a period of years. Power levels in the kw range are achievable.

349. Knoernschild, E.
PROBLEME DER ENERGIEWANDLUNG MIT IONENKONVEKTION [PROBLEMS OF ENERGY CONVERSION BY ION CONVECTION].
Raumfahrtforschung, 9:7-16, Jan.-Mar. 1965. In German.

Energy generators aboard space vehicles should guarantee a long-duration reliable operation for months or years. This goal seems to be easier to realize with systems without moving parts, i. e. by thermionic or magnetohydrodynamic generators. Far less known are systems using the ion convection for energy conversion; in principle the inversion of the ion propulsion. While in this case ions are accelerated in an electric field by consumption of electric energy in the case of an ion converter the working medium is expanded and accelerated within a nozzle. The working medium then is ionized and forced to run against the self induced electric field. The reduction of the kinetic energy of the working fluid is converted into electric energy. The operational characteristics of such an ion convection converter are shown and possible applications discussed; published proposals and test results are examined. An optimization of the ion convection converter shows that this method can compete in certain areas with the known direct conversion methods.

350. Kobayashi, M., Ishikawa, Y., and Hayashi, K.
SOLAR BATTERIES FOR THE USE AS THE POWER SOURCE OF UNATTENDED U.H.F. REPEATERS.
NEC Research and Development, 1:20-25, Oct. 1960.

The transmitter-receiver equipment, which has an average consumption of 4.5 W, is supplied by NiCd cells charged from solar batteries with a peak output of 70 W.

351. Koch, W. and Menke, H.
TECHNISCHE ASPEKTE DER MODERNEN PLASMAFORSCHUNG [TECHNICAL ASPECTS OF MODERN PLASMA RESEARCH].
ETZ, 84:65-75, Feb. 11, 1963. In German.

Plasma physics, due to the intensive efforts to perfect controlled nuclear fusion, and to research on space flight, has developed into a large, independent, technical field of research. Beginning with nuclear fusion research, a number of other new fields of application of the fourth state of aggregation of matter were found for technical purposes. These are mainly magnetohydrodynamic generators for the generation of electricity from thermal energy without the intervention of a mechanical stage, and electrical space flight drive systems with particularly good methods of control. For electrical engineering this field of plasma technique presents a number of problems, and several special ones are discussed in more detail.

352. Koerner, T. W. and Paulson, J. J.
NUCLEAR ELECTRIC POWER FOR SPACE MISSION.
Aerospace Engineering, 20:18-19, 44-46, 48-49, May 1961.

Study considering nuclear electric power, applications for planetary, interplanetary and lunar exploration, for secondary power requirements, and for the final phases of propulsion to place a spacecraft at its destination. Radioisotope thermoelectric generators are considered most suitable for use where a small amount of power for an extended period is required.

353. Koerner, T. W.
STATIC POWER CONVERSION FOR SPACECRAFT.
Astronautics and Aerospace Engineering, 1:89-92, May 1963.

As spacecraft increase in complexity, power conditioning becomes an increasingly important, sophisticated aspect of systems design.

354. Kofskey, M. G. and Glassman, A. J.
TURBOMACHINERY CHARACTERISTICS OF BRAYTON CYCLE SPACE-POWER-GENERATION SYSTEMS.
New York, American Society of Mechanical Engineers, 1964, 46 p.

Results of an analytical study of turbomachinery requirements and configurations for Brayton cycle space-power systems. Basic turbomachinery requirements are defined and typical effects of such system design parameters as power, temperature, pressure, and working fluid on turbomachinery geometry and performance are explored. Typical turbomachinery configurations are then presented for systems with power outputs of 10, 100, and 1000 kw.

355. Kohl, J.
EXOTIC POWER SOURCES.
Electrical West, 131:38-41, Jly. 1964.

The operating principles of controlled fusion, MHD, thermionic emission fuel cells, and thermoelectric generators are outlined. Anticipated efficiencies and sizes, fuels and heat sources required, applications, and current status of research are discussed.

356. Kopecky, J. and Kajfosz, J.
NUCLEAR BATTERIES.
Jaderna Energie, 10:203-210, June 1964. In Czechoslovakian.

A review is given on the direct conversion of nuclear into electric energy. Individual direct conversion methods are described and compared together from the point of view of its properties and utilization possibilities. The main perspectives of further development of this branch are indicated.

357. Kordesch, K. V.
LOW TEMPERATURE FUEL CELLS.
Institute of Electrical and Electronic Engineers. Proceedings, 51: 806-812, May 1963.

Fuel cells have emerged from the research laboratories and are now in the state of being actively developed for various military and commercial purposes. The paper tries to describe the principal problems which had to be overcome to build reliably operating, relatively inexpensive cells. The different systems presently used are compared with each other and the possibilities of the use of cheap hydrocarbon fuels in low temperature cells is discussed.

358. Kortier, W. E. and Pobereskin, M.
RADIOISOTOPE-FUELED THERMOELECTRIC GENERATORS.
Battelle Technical Review, 13:3-8, Dec. 1964.

The need for dependable, unattended sources of power is being filled increasingly by radioisotope-fueled thermoelectric generators. Here is a discussion of problems involved in their design and some steps being taken for improving such devices.

359. Krausz, A.
NON-NUCLEAR POWER SUPPLIES.
Space/Aeronautics, 44:118-122, 1965.

Review of present trends in research on various nonnuclear power sources for spacecraft. In discussing solar power supplies, special mention is made of the development of large, deployable solar arrays and thin-film photovoltaic devices. The realization of the full potential of focused solar energy is said to require the use of static energy converters like the thermionic diode rather than dynamic conversion methods. Three kinds of alkaline batteries for supplying power to spacecraft during dark time are discussed, together with certain measures that can be taken to minimize the effects of gassing in the event of overcharge. Three fuel-cell systems that have been developed for the US manned space program are described. Certain remarks are made concerning the devices needed for generating electrical power in the form required by the power-using equipment.

360. Krausz, A.
POWER SOURCES.
In Balakrishnan, A. V. ed., Space Communications, p. 213-250. New York, McGraw-Hill Book Co., Inc., 1963.

General considerations regarding power requirements for satellites or spacecraft carrying communications or data-processing equipment. The primary energy sources available are described, and methods of converting primary energy to usable electrical energy are discussed in some detail, including photovoltaic energy conversion, thermionic conversion, and batteries and fuel cells. Briefly described is the electric-power-supply subsystem for an orbiting geophysical observatory.

361. Kueser, P. E., McCabria, J. L. and Naumer, D. A.
EXPERIMENTAL RESULTS FROM A SOLAR HEATED THERMOELECTRIC GENERATOR UTILIZING THERMAL ENERGY STORAGE.
IEEE Transactions on Aerospace, AS-2:675-681, Apr. 1964.

Presentation of data on a nominal 14-watt solar thermoelectric generator utilizing thermal energy storage. During operation, thermal energy was supplied to the unit for 55 minutes of each 90-minute cycle. The generator continued to supply electric power during the remaining 35 minutes, utilizing the stored thermal energy. This cycle simulates a 300-mile Earth orbit.

362. Kueser, P. E., Merrill, P. S. and Tauch, F. G.
STATIC NUCLEAR THERMOELECTRIC SYSTEM FOR SPACE.
Applications and Industry, 64:402-405, Jan. 1963.

A completely static nuclear-powered thermoelectric generator is discussed. The reactor, designed for SNAP-10, uses U_{235}-zirconium-hydrided fuel moderator and is capable of operating a thermoelectric generator at a hot-side temperature of 1,000 to 1,200°F. A prototype thermoelectric generator is described that produced 250 watts of electric power at space operating temperatures. Waste-heat radiator for the system, having constant and tapering fin thicknesses, are discussed.

363. LaBatte, J. J.
400 CYCLE TO 400 CYCLE BUFFER POWER SUPPLY FOR INERTIAL GUIDANCE SYSTEM.
IEEE Transactions on Aerospace, AS-2:1006-1012, Apr. 1964.

Application of a unique form of motor-generator set as an isolating device in the power system of a space vehicle. The M-G set acts as a buffer - i. e., it isolates electronic circuitry comprising the inertial guidance system from primary power line transients. The set consists of: an extremely low-slip polyphase induction motor driving a unique brushless ac generator, and an integral voltage regulator. A description of the rotating machinery of a typical set is given.

364. LaFond, C. D.
BATTERIES RETAIN THEIR POWER ROLE.
Missiles & Rockets, 6:15-17, Aug. 24, 1959.

Survey shows that electrochemical batteries are desirable auxiliary power sources for many missile and satellite uses -- sales expected to grow 10-fold.

365. Lalli, V. R.
PYROTECHNICS FOR EFFICIENT PREHEATING OF SPACE POWER SYSTEMS.
Space/Aeronautics, 44:99, 101, 102, 104, 106, Nov. 1965.

Discussion of pyrotechnics for efficient preheating of space power systems by simple, lightweight chemical blends that produce heat pyrotechnically. Such a blend consists of some active element like boron, zirconium or magnesium and some compound like molybdenum trioxide, barium chromate or cupric oxide. Ignited by a rise in the temperature of any portion of the blended chemicals, it reacts exothermically, producing fixed quantities of heat with an accuracy of 2 to 3% of the desired temperature. The proper pyrotechnic blend depends primarily on the power system to be preheated. Theoretical analysis shows that a preheating system should weigh about 24 lb. It appears that pyrotechnics should be the first choice for preheaters.

366. Lanaman, J. H., Morrow, R. J. and Tesdall, D. W.
CHILLDOWN ELECTRICAL SYSTEM FOR S-IVB SPACE VEHICLE.
IEEE Transactions on Aerospace, AS-3:Suppl.: 173-178, June 1965.

Description of the electrical system used to drive the chilldown motor pumps on the S-IVB space vehicle. This system consists of a 56-v battery supplying power to the two three-phase solid-state inverters which in turn drive two cryogenic motor pumps. Included is a short description of the overall chilldown system requirements. The advantages of the ac system over the dc system are discussed with emphasis on weight and reliability. Two functionally identical 1.5-kva inverters were designed. One inverter uses germanium transistors in the output stage while the other uses silicon transistors. Both inverters were designed to have a quasi-square wave output. The inverter circuitry is described and the advantages of each are discussed including a comparison of weight, size, operating temperature, efficiency and voltage rating.

367. Lander, J. J.
SEALED SILVER-ZINC BATTERIES.
New York, American Institute of Aeronautics and Astronautics, 1964, 8 p. (Paper 64-749.)

Presentation of a systematic approach used to elucidate and optimize the important internal design factors governing cycle life and energy yield of hermetically sealed secondary silver-zinc batteries. Data are presented which establish the effects on cycle and mercury content in the zinc plate. Addition of palladium to the positive plate is shown to increase recharge capability. It is stated that data for energy yield of plate packs where total equivalent amounts of active material are distributed among several plate number combinations show that yields increase as plate thickness increases. Sealed operation was accomplished for hundreds of cycles with minor internal pressure build-up by controlling the upper limit of charge voltage. The following conclusions are made: 1) sealed operation of silver-zinc batteries is practical, 2) substantial progress has been made in improving life, and 3) considerable improvement in performance is still possible.

368. Lang, R. and Lubin, B. T.
A BASIC THERMOELECTRIC UNIT - SEEKING EXPERIMENTAL AND THEORETICAL PERFORMANCE AGREEMENT.
Aerospace Engineering, 21:6-15, illus., Feb., 1962.

A logical procedure for the design of a solar thermoelectric power unit for planetary fly-by vehicles or orbital satellites is described. Theoretical performance is shown to agree with the results of prototype tests.

369. Langpape, R.
THE THERMIONIC ELEMENT AND ITS SIGNIFICANCE FOR SPACE NAVIGATION.
Atomwirtschaft, 9:121-125, Mar. 1964. In German.

The application of thermionic elements in combination with suitable heat sources, for example a high temperature reactor, for the generation of power in a space vehicle is discussed.

370. Lashkarev, G. V., Taranets, A. M. and Fomenko, V. S.
SOLAR PHOTOELECTRIC BATTERIES.
Novye Istochniki Elektricheskoi Energii, Kiev, p. 71-86, 1962. In Russian.

371. Lawson, L. J.
FUEL CELL POWER CONVERSION BY THE A. C. LINK TYPE STATIC INVERTER.
IEEE Transactions on Aerospace and Electronic Systems, AES-2, Suppl.: 160-163, Jly. 1966.

The recent development of a lightweight, highly efficient ac link-type static inverter (cycloinverter) provides a new power conversion candidate for consideration by the aerospace systems designer. This inverter can be used in power systems provided by fuel cells, conventional aircraft dc generators, or batteries. The ac link inverter has become fully practical by selection of a system implementation in which each power modification necessary for the generation of high-quality ac power is accomplished in the most efficient manner which will not contribute significantly to weight. The resulting system combination of chopper, transformer, cycloconverter, and filter is superior in kva per pound and efficiency to conventional inverters for the same system requirements. The new inverter has also been applied to ac electric adjustable speed drives using polyphase squirrel cage induction motors for lightweight aerospace system applications.

372. LeBlanc, A. R. and Grannemann, W. W.
THERMIONIC GENERATOR FOR RE-ENTRY VEHICLES.
Institute of Electrical & Electronic Engineers, Proceedings, 52:1302-1310, Nov. 1964.

The design of a hypersonic plasma thermionic generator for use on reentry vehicles is described. Calculations were made to decide electrical parameters of the experimental device. A test model was built and inserted in a nitrogen or an argon plasma jet to simulate reentry conditions. Graphite was the only materials of those tested that met, somewhat, the qualifications required for operation of the generator.

373. LeDuc, J. A. and Lurie, C.
BARIUM FUEL CELL SYSTEMS.
In Collins, D. H. ed., Batteries 2; International Symposium, 4th, Brighton, England, September 29-October 1, 1964, Proceedings, p. 371-383. Oxford, Pergamon Press, Ltd., 1965.

Study of fuel cell systems using solid metallic barium as the fuel electrode and oxygen or chlorine as the cathode. Experiments on such cells were conducted using various aqueous electrolytes. The results indicate that these cells can operate well at high current drain at ambient temperature and pressure, and that they are theoretically capable of operating at higher net energy densities per unit volume than any other electrochemical power source in use or under consideration.

374. Lee, H. S. and Corcoran, E. G.
ADVANCED DYNAMIC POWER GENERATING SYSTEMS FOR SPACE VEHICLE APPLICATIONS.
International Astronautical Federation, International Astronautical Congress, 17th, Madrid, Spain, Oct. 9-15, 1966, Paper. 7 p.

Comparison of the Rankine and Brayton cycles for application in power generating systems for spacecraft. The Rankine cycle uses a two-phase working fluid and a pump for fluid circulation; the Brayton cycle uses a compressor to circulate an inert gas which acts as the working fluid. The former system has the advantages of (1) high thermodynamic efficiency for a given operating temperature range, (2) minimum radiator and boiler surface areas because of the nearly isothermal heat rejection and heat addition processes, and (3) lower back work for cycle operation. The major advantages of the Brayton-cycle system are (1) use of a single-phase inert gas as the working fluid, thus eliminating the problem of separating a two-phase fluid, (2) reduction of contamination and materials compatibility problems, and (3) lower development risks than for the Rankine-cycle system employing liquid metals.

375. Lee, J. M.
THERMOELCTRIC GENERATOR FOR PORTABLE EQUIPMENT.
Electronics, 19:196,202, May 1946.

Banks of chromel-P/constantan thermocouples embedded in ceramic material and heated by a gasoline burner give power outputs up to 20 watts at 12 volts. The couples have a useful life of about 2000 hours, and the generator weighs about 2-1/2 pounds per watt output.

376. LeGrives, E.
INTERET DE LA CONCENTRATION DU RAYONNEMENT SOLAIRE POUR LES CONVERTISSEURS SPATIAUX [SIGNIFICANCE OF CONCENTRATING SOLAR RADIATION FOR SPACE CONVERTERS].
International Astronautical Federation, International Astronautical Congress, 16th, Athens, Greece, Sept. 13-18, 1965, Paper. 51 p. In French.

Evaluation of the respective merits of different types of direct and indirect converters with particular emphasis on preconcentration of solar radiation. The future development possibilities of

thermophotovoltaic generators of the p-i-n type are discussed. Methods for concentrating solar radiation are described in terms of the optical degree of precision required for the desired temperature level and the mode of deployment. The formulas given for a conic reflector with an axial column and a reflector of the thin, stabilized Fresnel disk type should permit attaining the dimensions required for converters with more than 100 kw power. Such high-power solar generators could find application in missions for exploring the solar system. Deep penetrations of the solar gravitational field can be expected using a heliothermal or helioelectric drive.

377. Leisenring, J. G.
COLLECTOR DESIGNED FOR SOLAR-THERMIONIC SPACE SYSTEM.
Society of Automotive Engineers Journal, 68:50-55, Aug. 1960.

This paper describes thermionic converters, their operating characteristics, and their use in power conversion systems. It presents a detailed analysis of a solar-thermionic space power system. A solar collector design study is part of this analysis.

378. Leisenring, J. G.
THE THERMIONIC POWER CONVERTER AND ITS APPLICATION.
New York, Society of Automotive Engineers Inc. 1960, 29 p. (Paper 159C.)

The fundamental operating characteristics of the thermionic converter and its applications are described. The heat source may be solar, chemical, or nuclear. The production of electrical energy for use in ground, space, airborne or sub-surface systems by thermionic conversion has no limitation if the heat source and heat sink requirements can be met. One particular system, a solar-thermionic space power system, is analyzed in detail.

379. Lemaignen, J.
DESCRIPTION DES PRINCIPAUX TYPES DE PILES A COMBUSTIBLE [DESCRIPTION OF THE PRINCIPAL TYPES OF FUEL CELLS].
Entropie, p. 74-72, Mar.-Apr. 1967. In French.

Description of fuel cells, classified according to the nature of their electrolytes: solid, molten, or aqueous. Cells with a refractory electrolyte operating at high temperature, cells with ion exchange diaphragms, cells of the Broers and Ketelaar alkaline carbonate type, and cells with an aqueous electrolyte, of which the Bacon cell is the prototype, are considered. Included in the latter category are cells with molten fuel and Redox cells. For each, the principle of operation is outlined, a typical structure is described, and the performance obtained is given. An attempt is made to compare the different developments and to summarize their particular fields of application.

380. Lemaignen, M.
REVUE DES PILES A COMBUSTIBLE ET, PLUS SPECIALEMENT, DES PILES A MEMBRANE EN VUE DE LEUR APPLICATION SPATIALE [REVIEW OF FUEL CELLS, ESPECIALLY MEMBRANE CELLS, AND THEIR SPACE APPLICATION].
Doc-Air-Espace, p. 3-12, Mar. 1964. In French.

Review of various types of fuel cells. Their history is briefly recalled. Fuel cells functioning at very high temperatures (1,000°C and above) are discussed, and their performances given. They are considered of interest because of the possibility of utilizing hydrocarbons as fuel. High-temperature cells (500-800°C) are described. They are intended to use natural gas, with, ultimately, double the efficiency of present installations. The Bacon cell operates at 200-250°C, with favorable characteristics, but requires among other things an extreme degree of purity of oxygen and hydrogen. The US General Electric fuel cell is briefly mentioned. Low-temperature cells with liquid and solid electrolytes receive attention. The performances of membrane cells are discussed with reference to polarization, efficiency, weight, and their applicability as a source of energy for space vehicles. The French Thomson-Houston Company is undertaking fundamental research in the field of fuel cells.

381. Leonard, A.
OUT-OF-PILE THERMIONIC SPACE POWER SYSTEMS USING A GASEOUS HEAT-TRANSFER FLUID.
In Intersociety Energy Conversion Engineering Conference, Los Angeles, Calif., September 26-28, 1966, Technical Papers, p. 332-341. New York, American Institute of Aeronautics and Astronautics, 1966.

The out-of-reactor thermionic power system, employing an inert gas as the medium for heat transfer from the reactor to the thermionic converters, is shown to promise specific masses comparable with current in-reactor concepts because of high allowable gas temperatures. This system, moreover, has two important advantages over the in-pile system - namely (1) by separating the converter and the reactor fuel elements, it simplifies the structure and reduces the development difficulties of both of these items, and (2) the testing rate of out-of-pile thermionic converters is much faster than that of in-pile converters. On the other hand, the out-of-pile system takes on difficult high temperature materials problems and thermionic element design problems associated with the large variation in the heat-transfer-fluid temperature as it passes through the converter. The creep-rupture problem for this system is therefore discussed, and the optimization of the converter configuration is analyzed in some detail.

382. Leovic, W. J. and Mueller, M. W.
DESIGN OF A SOLAR-POWERED THERMIONIC DIODE.
Electrical Engineering, 79:979-986, illus., Dec. 1960.

Intense interest in thermionic conversion in the field of space power supplies rests on two inherent properties of this type of conversion process: (1) solar energy can be converted to electric energy without use of moving parts of any kind; and (2) diode anode can operate at temperatures between 600 and 1500°K permitting efficient rejection of heat by radiation only. Diode has additional advantages of instant and repeatable start-stop capabilities.

383. Leovic, W. J., Mueller, M. W. and Stevenson, C. G.
PERFORMANCE TEST OF A CUBICAL CAVITY SOLAR THERMIONIC GENERATOR.
New York, American Rocket Society, 1962, 11 p. (Preprint 2554-62.)

A solar test program carried out on a prototype thermionic generator is described. The program, which is designed to evaluate the performance of the generator in conjunction with a five-foot precision solar concentrator, shows the ability of such a combination to produce very nearly its design power output levels in a space environment. A description is given of all specialized equipment and techniques employed in carrying out the tests and evaluations. The pertinent data and results are summarized and analyzed for all major phases of the solar test effort. The major phases include the evaluation of concentrator efficiency, flux profile and power distribution measurements, cavity absorber efficiency, the environmental chamber and the influence of the transparent vacuum enclosure, a comparison and correlation of solar test generator performance with laboratory test data, and an extrapolation of the earth-bound test results to the true space environment.

384. Leovic, W. J. and Kamien, C. Z.
SOLAR THERMIONIC POWER SYSTEMS DEVELOPMENT.
American Institute of Aeronautics and Astronautics, 1964, 38 p. (Paper 64-735.)

The results of solar evaluations of a 100 watt thermionic generator conducted under a solar flux range of 80 to 100 watts/ft^2 are presented. Generator performance optimization, misorientation, cyclic and transient response tests were accomplished. Good correlation of the generator's solar performance with laboratory performance was obtained and indicated that at the 130 watts/ft^2 solar flux level of outer space, the generator would be capable of achieving the full design power output of 100 watts. Generator power output was reduced up to 10% under a solar concentrator misorientation of 6 minutes of arc, illustrating the need for high accuracy concentrator orientation devices. In addition, results of cyclic and continuous life test of practical hardware thermionic converters are given for three design iterations. Discussion of design details, and life limiting characteristics of each design, through a two year development period illustrate the progress made in extending the continuous life operation to over 3600 hours and cyclic life operation beyond 2330 deep thermal cycles (55 minutes ON, 35 minutes OFF). These converters employ a tantalum emitter operating at a

design temperature of 2000°K and a molybdenum collector at 900°K. They are rated at 16.5 watts at 1.0 volts or 24.8 watts at 0.7 volts.

385. Lespinasse, B.
LA CONVERSION DE L'ENERGIE LUMINEUSE EN ENERGIE ELECTRIQUE - LES CELLULES PHOTOVOLTAIQUES AU SILICIUM. III. [CONVERSION OF LUMINOUS ENERGY TO ELECTRICAL ENERGY - SILICON PHOTOVOLTAIC CELLS. III].
Sciences et Industries Spatiales, 2:71, 73-80, 1966. In French.

Review of manufacturing techniques of silicon photovoltaic cells, a consideration of the special problems concerned with the utilization of solar cells in space, and a description of the chief factors affecting the design of a solar generator. Single crystal growing techniques, diffusion methods, and electrode forming procedures are discussed. The action of electrons and protons on silicon solar cells is considered. The calculations for determining the area required for a given power output of a solar generator are developed for the case of a stabilized and for a nonstabilized satellite.

386. Lespinasse, B.
LA CONVERSION DIRECTE DE L'ENERGIE CHIMIQUE EN ENERGIE ELECTRIQUE - BATTERIES ET PILES A COMBUSTIBLE. II. [DIRECT CONVERSION OF CHEMICAL ENERGY TO ELECTRICAL ENERGY - BATTERIES AND FUEL CELLS. II].
Sciences et Industries Spatiales, 1:63-68, 1965. In French.

Discussion of rechargeable chemical batteries. Such batteries must be able to withstand numerous charging and discharging cycles, be leakproof, have high specific capacity, and must function satisfactorily at temperatures from -10 to +40°C. The chemical reactions involved in nickel-cadmium batteries are described, followed by similar consideration of silver-cadmium batteries. The two types are compared, and possible improvement by use of an auxiliary electrode is discussed.

387. Lespinasse, B.
LA CONVERSION DIRECTE DE L'ENERGIE THERMIQUE EN ENERGIE ELECTRIQUE - LES DIODES THERMIONIQUES [THERMIONIC DIODES - DIRECT CONVERSION OF THERMAL ENERGY INTO ELECTRICAL ENERGY].
Sciences et Industries Spatiales, 3:41-48, 1967. In French.

Consideration of thermionic diodes, in which the working fluid is an electron gas, as a means of converting thermal energy directly into electrical energy. The generalities of thermionic conversion are discussed. A thermionic diode consists of two electrodes - an emitter and a collector - placed closely to each other. The emitter, at high temperature, discharges electrons across the gap to the collector, which is at low temperature, causing a current to pass in the exterior circuit. The diode may be of vacuum or gas type. Cesium plasma diodes are described in detail.

388. Leventhal, E. L. and Berganini, D. F.
SNAPOODLE DEMONSTRATION DESIGN STUDY.
In National Aerospace Electronics Conference, 17th, Dayton, Ohio, May 10-12, 1965, Proceedings, p. 151-164. Dayton, Institute of Electrical and Electronics Engineers, Dayton Section, 1965.

Description of SNAPOODLE, a device for simultaneous generation of propulsive thrust and auxiliary electric power. In this device a POODLE isotope thrustor is coupled to an appropriate thermal-to-electrical energy converter to produce a combined isotope-fueled space engine plus electric-power generator. To prevent the isotope fuel from exceeding its melting temperature under any conditions, the POODLE is passively controlled. This control is effected by designing the thrustor thermal shield to function also as a temperature-limiting radiator, a technique which permits a complete shutdown (zero thrust) capability, but it requires that approximately 40% of the isotope thermal energy be radiated away to space. SNAPOODLE involves the emplacement of a thermoelectric converter around a POODLE thrustor in such a manner that the waste heat passes through the converter system before being radiated to space, allowing part of that heat to be converted to electrical power. Thus, it is possible simultaneously to generate both thrust and electrical power from a single unit at a higher total thermal efficiency than either component separately.

389. Leventhal, E. L.
SNAPOODLE ISOTOPE THRUSTER/ELECTRIC POWER UNIT.
In Radioisotopes for Aerospace; Proceedings of the First Symposium on Radioisotope Applications in Aerospace, Dayton, Ohio, February 15-17, 1966. Part 2 - Systems and Applications, p. 409-426. New York, Plenum Press, Division of Plenum Publishing Corp., 1966.

SNAPOODLE is a radioisotope powered device designed to provide a spacecraft with both electric power and thrust. It combines in a single unit a thermoelectric generator and a POODLE type thruster. The paper describes the SNAPOODLE concept, results of thermal analyses, and calculations of performance capability for a typical SNAPOODLE configuration. The potential savings realized by combining the electric power and low thrust propulsion functions in a single SNAPOODLE unit are described. Performance data are given for both the thrust and no-thrust conditions.

390. Levine, J. D.
OXYGEN AS A BENEFICIAL ADDITIVE IN CESIUM THERMIONIC ENERGY CONVERTERS.
Journal of Applied Physics, 38:892-893, Feb. 1967.

Description of a technique for direct controlled diffusion of pure oxygen into the interelectrode space of operating thermionic converters. A semipermeable silver membrane is used as the electron collector in an oxygen diffusion process that proved beneficial for converter performance.

391. Lewellen, W. S. and Grabowsky, W. R.
NUCLEAR SPACE POWER SYSTEMS USING MAGNETOHYDRODYNAMIC VORTICES.
ARS Journal, 32:693-700, figs., May 1962.

A magnetohydrodynamic generator is proposed as a conversion mechanism for a Rankine-cycle electric power system using a nuclear reactor as the energy source. Fundamental relationships existing between the various parameters of the magnetohydrodynamic vortex are presented and discussed. A comparison of the vortex and linear channel MHD generators is made, and it is demonstrated, that under certain conditions the vortex is superior. Certain design considerations relative to the working fluid and fabrication materials are given. The system's performance is compared to a similar system using a mechanical turboalternator for conversion. The chief advantage of the magnetohydrodynamic system is that it is designed to operate at considerably higher temperatures than a high speed turbine, permitting the overall temperature level of the system to be raised accordingly. This yields a weight reduction of the order of 50% and higher for systems with power levels of 100 kw and higher.

392. Lieber, R., Kolodkin, S., Schneider, A. and Perkel, H.
PROGRESS IN MISSILE AND AEROSPACE AUTOMATIC CONTROL.
IEEE International Convention Record, 13(pt. 6):16-20, 1965.

Discussion illustrating how missile guidance and autopilot control systems based on array radar and digital computers can be rapidly adapted to a wide range of threats or environments. A description is given of space vehicle and satellite control systems which utilize on-board microcircuit computers and inertial devices to make possible the implementation of complex guidance laws having optimal properties in flexible situations. It is pointed out that guiding a vehicle to a target and/or maintaining attitude according to a desired program requires that means be provided for sensing the controlled vector, modifying the sensed value according to some desirable guidance law, and causing the resultant to be applied to the power elements of the vehicle.

393. Liebhafsky, H. A.
FUEL CELLS AND FUEL BATTERIES - AN ENGINEERING VIEW.
IEEE Spectrum, 3:48-56, Dec. 1966.

Discussion of the usefulness of fuel cells and fuel batteries, and of the problems relating to them. The conventional fuels for these devices - hydrogen, compromise fuels, and hydrocarbons - are investigated, and the efficiency, reliability and working life, and unit capital costs of fuel cells and batteries are studied. Electrical problems of the fuel battery and possible future applications (such as for central power stations) are considered.

394. Liebhafsky, H. A. and Grubb, W. T., Jr.
THE FUEL CELL IN SPACE.
ARS Journal, 31:1183-1190, Sept. 1961.

Survey of fuel cell technology for space operations. It is concluded that if the severe reactivity and invariance requirements can be met even moderately well, the device should prove useful on missions too long for primary batteries. Fuel cells should also prove an attractive alternative to secondary batteries on extremely long missions in which fuel can be regenerated by using another form of energy, preferably that of the sun.

395. LIGHTWEIGHT SOLAR CONCENTRATOR DEVELOPMENT.
Solar Energy, 5:24-28, illus., Jan,-Mar. 1961.

The objective of the present research program is to develop a lightweight solar concentrator that will provide sufficient solar energy for space vehicle power conversion equipment. Solutions to processing problems such as tooling and parting of the lightweight replica mirror are discussed.

396. Linden, D.
ADVANCED POWER SOURCES FOR COMMUNICATION ELECTRONICS.
Institute of Radio Engineers, Transactions. MIL-4:497-501, illus., Oct. 1960.

Portable electrical power sources are being used in increasing numbers for a variety of applications on the ground and in outer space. The trend to miniaturization and transistorization has accelerated this practice. Chemical, nuclear, and solar energy are the three prime sources that are being used in power sources which will fulfill the new requirements. Each of these sources, in combination with new electrical conversion devices, has advantages and unique characteristics which make it desirable for this application. The characteristics of various types of recently developed electrical power sources are described and compared, and data are presented which illustrate the best operating conditions for each system.

397. Linden, D. and Daniel, A. F.
NEW BATTERIES FOR THE SPACEAGE.
Electronics (Bus. ed.) 31:59-65, illus., Jly. 18, 1958.

Limitations and applications of some of the latest developments, including the thermal cell, are discussed. Included is data to aid in the selection of batteries for present and future missile applications.

398. Linden, D. and Daniel, A. F.
NEW POWER SOURCES FOR SPACEAGE ELECTRONICS.
Electronics, 32:43-47, Mar. 20, 1959.

Chemical, nuclear, and solar energy are prime sources expected to fulfill requirements for portable electrical power in space. Descriptions and tables are given that indicate characteristics and potentialities of each.

399. Lindley, B. C.
THE APPLICATION OF NUCLEAR ENERGY FOR LARGE-SCALE SPACE POWER.
British Interplanetary Society Journal, 19:92-98, May-June 1963.

Possible types of nuclear reactors and energy convertor suitable for the generation of power in space are surveyed. Estimates of probable performance are given.

400. Lindley, B. C.
THE PROSPECTS FOR CLOSED-CYCLE MPD POWER GENERATION.
In Engineering Developments in Energy Conversion; International Conference on Energetics, University of Rochester, Rochester, N. Y., August 18-20, 1965, Proceedings, p. 125-140. New York, American Society of Mechanical Engineers, 1965.

Discussion of the practicability of energy conversion using closed-cycle MPD systems with cesium-seeded monatomic gases as the working fluid. Types of ionization techniques and their practical implementation are outlined. Various technical aspects of closed-cycle conversion - such as operating pressure, specific power, choice of heat source, and superconducting field coils - are discussed. Some recent experiments are briefly described, and some results are given. It is concluded that MPD plants could be in use for special applications - such as power supplies for space vehicles and satellites - in a few years.

401. Lindley, B. C.
SPACE DEMANDS NUCLEAR POWER SYSTEMS.
Engineer, 194:457-458, Oct. 5, 1962.

Attention must be given to the interaction between the power source and the space system. The primary areas to be studied involve thermal, electrical, and radiation integration. The techniques used to analyze these interfaces are straightforward, standard analytical procedures, and in general problems can be easily resolved. It is evident, however, that the isotopic power system is not a simple plug-in device. It can be best applied to space systems specifically designed for its use.

402. Ling, R.
NEW ENERGY CONVERSION TECHNIQUES FOR SPACE VEHICLES.
Society of Automotive Engineers Journal, 67:56-57, Dec. 1959.

Discussion of chemical, solar, and nuclear systems for secondary power sources with the objectives of longer duration of operation and improved recycling characteristics at high temperatures.

403. Lingle, J. T.
RELIABLE ENERGY CONVERSION POWER SYSTEMS FOR SPACE FLIGHT.
IEEE Transactions on Aerospace, AS-3, Suppl.:543-549, June 1965.

Description of low-voltage converter-regulators, which provide the key to the utilization of new energy-conversion power sources in future space applications. It is now possible to use transistor-converters to boost the low voltage level of thermionic, fuel-cell, thermoelectric, and electrochemical sources to a higher, more usable regulated voltage. Improved low-voltage converter-regulators have efficiencies between 70 and 90%. This approach will allow the designer of space power systems to achieve higher reliability with single-cell sources coupled to low-voltage converter-regulators.

404. Linkletter, J.
IS THIS THE 10-YEAR BATTERY?
Popular Mechanics, 115:112-114, 237, 255, Feb. 1961.

Describes a nickel-cadmium ceramic seal battery which will last ten years in outer space.

405. Litz, L. M. and Kordesch, K. V.
TECHNOLOGY OF HYDROGEN-OXYGEN CARBON ELECTRODE FUEL CELLS.
In Fuel Cell Systems, p. 166-187, Washington, D. C., American Chemical Society, 1965.

Some considerations involved in producing rugged, long life, high current density batteries based on the carbon electrode fuel cell are presented.

406. Lloyd, W. W.
THE THEORY AND APPLICATION OF SOLAR CELLS.
British Interplanetary Society Journal, 19:110-117, Jly-Aug. 1963.

The theory of photovoltaic action is outlined, mention being made of the effect of temperature and radiation bombardment, and methods of manufacture are described. Applications in satellites and in land-based devices are considered.

407. Lodzinski, R. J.
5-KW HYDROCARBON-AIR FUEL CELL POWER SOURCE.
In Szego, G. C. and Taylor, J. E., eds., Space Power Systems Engineering p. 1043-1048, New York, Academic Press, Inc., 1966.

A fuel cell power source is described which utilizes a reformer to supply the hydrogen and produces a net output of 5-kw electrical power at 110 v and 60 cps. Major emphasis is placed upon the fuel cell temperature and moisture control systems. A compressor in the reactant air system provides the required oxygen for fuel cell operation. This air is pumped through a scrubber that removes the

carbon dioxide with an aqueous KOH solution. The scrubber unit also heats and humidifies the air prior to entering the cell. By cooling the fuel cell exhaust air stream, some water is recovered to aid in making the system self-sufficient in moisture. A vacuum produced in a chamber adjacent to the hydrogen side of the cell maintains finer moisture control. The fuel cell module temperature is controlled by a forced circulation liquid cooling loop, which is also used for heating the module during startup. A hydrogen storage system provides fuel to the cells during rapid load changes until the reformer can produce enough fuel to carry the load. Batteries, charged during cell operation, are used to power the required auxiliaries during startup and shutdown.

408. Lof, G. O. G.
DEVELOPMENT OF SOLAR ENERGY FOR INDUSTRIAL AND DOMESTIC USES.
In U. S. Congress, 86th, 2nd Session. Joint Committee on Atomic Energy. Subcommittee on Research and Development. Hearings. Frontiers in Atomic Energy Research, March 1960, p. 359-366, Washington, D. C. Government Printing Office, 1960.

In the section on small scale power generation, photoelectric, thermoelectric and thermionic power generators are briefly discussed. Mention is made of solar energy converters or collectors, solar refrigeration, auxiliary power in space, and long range research in solar power.

409. Loferski, J. J.
RECENT RESEARCH ON PHOTOVOLTAIC SOLAR ENERGY CONVERTERS.
Institute of Electrical and Electronic Engineers. Proceedings, 51:667-674, May 1963.

This paper contains a review of recent work on photovoltaic cells fabricated from semiconductors other than silicon; the effects of radiation on silicon n/p and p/n cells, and gallium arsenide p/n cells; and thin film photovoltaic cells.

410. Loftus, W. D.
CELL EQUALIZATION TECHNIQUES.
In 21st Annual Aerospace Electrical/Electronics Conference, Los Angeles, Calif., Oct. 9-11, 1963, p. 41-62, Aerospace Electrical Society, 1963.

Space vehicle power supply system requirements are presently most nearly fulfilled by certain alkaline secondary batteries coupled to solar cells. Inherent small differences in the capacity and internal resistance of individual cells become more diverse during life of the cycled battery. Voltage equalization and reversal protection of individual cells can prolong life and upgrade the battery performance. Equalization and anti-reversal devices have been designed for the nickel-cadmium system and experimental charge control circuits operated, with good results, for several hundred cycles.

411. Lombardo, A. R.
ELECTRONICS AROUND THE MISSILE. I.
Interavia, 19:1643-1646, Nov. 1964.

Description of the components and functions of the ground-support equipment used to maintain a continuous monitoring of Minuteman missile status and to control launch operations. The basic requisites imposed on the missile system (intercontinental range, high accuracy, capability of remaining in a state of readiness for long periods of time in an unmanned launch facility) have resulted in a widely dispersed installation mode, which in turn dictates complex, highly reliable support equipment that consumes up to 75% of both research and operational funds. Besides the determination of malfunctions and the control and initiation of launchings, the costs include the transportation, erection, and lowering of the missile into the silo; the supply of normal and emergency power and environmental control for personnel and equipment; the detection of security violations; data acquisition and communications links; and fail-safe mechanisms to prevent unauthorized or inadvertent launch.

412. Lombardo, A. R.
ELECTRONICS AROUND THE MISSILE. II.
Interavia, 20:71-75, Jan. 1965.

Description of the on-board electronics systems for the Minuteman Weapons System WS 133, their interdependence during systems readiness with the various auxiliary systems, and their in-flight operation, as well as their support and maintenance problems. The subjects treated are: (1) prelaunch readiness, (2) launch sequence, (3) guidance and control system development and test, (4) logistics and the operational missile, and (5) logistics and maintenance.

413. LONG-LIFE PROTOTYPE ATOM BATTERY SHOWN.
Aviation Week, 66:78, 80, Apr. 1, 1957.

A nuclear battery is described which will retain half-power for 2.6 years and can possibly be used for long-life space satellites.

414. Lubarsky, B. and English, R. E.
NON-PROPULSIVE POWER SYSTEMS FOR LONG-TIME APPLICATIONS.
Paper presented at CAI-IAS Joint Meeting, Montreal, Oct. 17-18, 1960. New York, Institute of the Aeronautical Sciences, 1960. n.p. (Paper 60-97.)

At present, solar photocells are the prominent source of power for longtime, nonpropulsive applications in space, and will maintain this prominence for powers below a kilowatt or so. Thermoelectric power supplies are being developed for use with solar radioisotopic, and reactor energy sources; these systems will be useful in those

applications involving impact or long periods of darkness. Turbo-generator systems employing solar and reactor energy sources are being developed for powers of several kilowatts and up; their use for nonpropulsive applications is several years away. Thermionic emitters are the basis for promising future systems, but their real potential cannot yet be evaluated.

415. Luft, W.
RANDOMLY ROTATING SPHERICALLY ARRAYED SILICON SOLAR ENERGY CONVERTERS.
Solar Energy, 4:33-39, illus., Oct. 1960.

Since spherical arrays of silicon solar cells are contemplated for the photovoltaic conversion of solar energy in certain satellite projects, various aspects of the solar cell matching problem arising from the nonuniform irradiation and temperature in an unoriented randomly spinning converter are discussed, and a sample calculation of power output is given.

416. Luft, W. and Escoffery, C. A.
SILICON PHOTOCELLS TO UTILIZE SOLAR ENERGY.
Automation Progress, 5:332-336, Oct. 1960.

The direct conversion of solar energy into useful heat or electricity will obviously constitute one of the major sources of future power. Every day, more energy reaches the terrestrial atmosphere from the sun than has been used up by mankind in all history. One of the more promising devices for utilizing it is the silicon photovoltaic cell with its conversion efficiency of about 12%. It is an obvious source of power for satellites and similar special applications. In quantities it could be produced for about $5/Kwh, but, at present, its first costs and also the added cost of storage batteries, which are usually needed, are its chief limitations.

417. Luft, W. and Nash, H.
TEMPERATURE CONTROL OF SILICON SOLAR CELLS IN SPACE ENVIRONMENT.
Semiconductor Products, 3:39-42, illus., June 1960.

The performance of silicon cells in converting radiant energy into electrical energy is dependent on the cell temperature. Most affected by temperature is the optimum power transfer characteristic, which has a temperature coefficient of -0.6% per degree centigrade. In a space environment the temperature of a solar collector is determined by the radiation equilibrium and hence by the optical characteristics of its surface. Conventional silicon solar cells have optical characteristics which produce higher surface temperatures than desired for good operating efficiency. Optical coatings have been developed which notably reduce the temperature, with corresponding increase in power output.

418. Luke, K. P.
PHOTOIONIZATION OF CESIUM ATOMS BY SOLAR RADIATION. APPLICATION TO A LOW-TEMPERATURE CESIUM THERMIONIC DIODE.
Solar Energy, 9:110-112, Jly.-Sept. 1965.

The result obtained indicates that solar radiation is capable of producing a significant number of cesium ions in the cesium thermionic energy converter.

419. Lukovtsev, P. D.
ELECTROCHEMICAL SOURCES OF ELECTRIC CURRENT.
Priroda 48:22-28, Dec. 1959. In Russian.

Electrochemical sources of electric power are relatively insensitive to external effects due to temperature, shocks, vibrations, moisture, etc. For this reason, electrochemical sources of current can be used to supply electric power in connection with many applications for which other sources of power are unsuitable. This includes applications on artificial satellites and pilot balloons.

420. Lunz, R.
SEALED CELLS WITH SOLAR CONVERTERS.
In Battery Research and Development Conference, 11th, 1957, p. 89-92, Fort Monmouth, N. J., U. S. Army Signal Engineering Laboratories, 1957.

Relates some details of an investigation to determine the voltage and cycle life characteristics of sealed and vented rechargeable cells when used with silicon solar converters as power supplies for electronics and instrumentation of satellites. Data obtained to date indicates that the use of sealed nickel-cadmium cells with solar converters offers great promise as the power supply for satellite operations.

421. Lutz, D. and others.
PARAMETERSTUDIE UEBER SCHNELLE REAKTOREN MIT THERMIONISCHEN KONVERTERN IN DER SPALTZONE (SYSTEM SRIKT) [PARAMETER STUDY OF FAST REACTORS WITH INCORE THERMIONIC CONVERTERS (SYSTEM SRIKT)].
Atomkern Energie, 10:368-374, Sept.-Oct. 1965.

Fast reactors with convection-cooled incore thermionic converters in the power range of 300 to 10 000 kW_{th} are investigated with respect to the application as power supply for space vehicles. For a large number of those thermionic reactors values for power weight and specific cost are presented. The aptitude of liquid metals as coolant for fast thermionic reactors in a power supply system for space vehicles is discussed.

422. Mackay, D. B. and Leventhal, E. L.
SOLAR TURBO POWER PLANT DESIGN.
Journal of Engineering for Power (ASME Transactions Series A). 82:315-323, Oct. 1960.

Discussion of the design of a lunar-based power plant powered entirely by solar radiation. Factors affecting power plant design and a discussion of a performance basis for a working fluid are also presented. Graphs and equations which illustrate theory, optimize results, and demonstrate inter-component relationships are included. A design for a new compact power plant is introduced.

423. Magee, V.
RADIATION RESISTANT HIGH EFFICIENCY SILICON SOLAR CELLS FOR SPACE VEHICLE POWER SUPPLIES.
In Conference on Components and Materials Used in Electronic Engineering, London, England, May 17-20, 1965. p. 14-1 to 14-7. London Institution of Electrical Engineers, 1965, (IEE Conference Publication No. 12).

The basic theory, manufacture, and performance evaluation of high-efficiency solar cells for space vehicles. The Sun provides 1.4 kw/m^2 of receiver-surface radiant energy. A 10% conversion by silicon solar cells can generate 140 watts of electrical power. The advantages of such cells are lightweight, high efficiency, and long-term reliability in space vehicles; the disadvantages are high cost and difficult fabrication problems for the large area arrays. Basic silicon solar cell theory is described. Cadmium sulphide thin-film technology may supplant the silicon solar cells in some fields of application.

424. Mahefkey, E. T. Jr. and Berganini, D. F.
RADIOISOTOPE POWER SUBSYSTEMS FOR SPACE APPLICATION.
New York, Society of Automotive Engineers, 1965, 12 p. (Paper 650791.)

Examination of the technical advancements necessary to realize the potential utility of radioisotope power subsystems. Isotope heat source and conversion devices are considered. A survey of isotope production costs and rates is presented. Isotope heat source, cladding compatibility, and operational safety requirements are reviewed. The performance of the Brayton (argon) and Rankine (mercury and Dowtherm "A") cycles is outlined. Thermoelectric and thermionic converter performance is also reviewed.

425. Mahefkey, E. T. Jr. and Manikowski, A. F. Jr.
RADIOISOTOPE POWER SUBSYSTEMS FOR SPACE APPLICATIONS.
In New Dimensions in Space Technology; Space Congress, 2nd, Cocoa Beach, Fla., April 5-7, 1965, Proceedings, p. 205-224. Cocoa Beach, Canaveral Council of Technical Societies, 1965.

Survey of the current technologies of energy converters, isotopic fuel form and cladding material compatibility, and launch and operational safety requirements.

426. Malohn, D. A.
1.5 KW SOLAR DYNAMIC SPACE POWER SYSTEM.
New York, American Institute of Aeronautics and Astronautics, 1964, 12 p. (Paper 64-725.)

Description of the concept and development status of a solar dynamic energy conversion system employing a Rankine cycle and using an organic substance as the working fluid. It is stated that the current hardware is designed to operate with the energy from a 10-ft ground test collector, which will provide approximately 0.24 kilowatts of useful electrical power. The boiler-heat receiver and the radiator/condenser have been designed for this power level; however, the rotating equipment is designed to produce 1.5 kw of electrical power. By modifying the turbine inlet nozzles, the combined rotating unit (CRU) is compatible with the 0.25-kw power level. Therefore, it will be possible to operate an entire system on solar energy (0.25 kw) and also meet the contract power requirement of 1.5 kw.

427. Mannal, C.
RECENT PROGRESS IN MAGNETOHYDRODYNAMICS.
Institute of Electrical and Electronic Engineers Transactions, NS-10:8-17, Sept. 1963.

This paper briefly reviews advances in magnetohydrodynamic power generation with particular reference to both land-based and aerospace designs. A brief comment is also made on aerodynamic advances.

428. Marsico, B. and Traversa, G.
LA CONVERSIONE DIRETTA DELL'ENERGIA NEI VEICOLI SPAZIALI [DIRECT ENERGY CONVERSION IN SPACE VEHICLES].
Rivista Aeronautica, 41:1755-1778, Dec. 1965. In Italian.

Discussion of energy sources to be used advantageously for direct conversion in various types of powerplant for spacecraft. It is noted that electricity is the most convenient form of energy for space vehicles when the criteria are suitability for on-board instruments, practicality, compactness, and ability to meet environmental-control and lighting requirements. The advantages of direct energy conversion are discussed.

429. Martin, O.
DIE SONNENSTRAHLUNG ALS HILFSENERGIEQUELLE FUR SATELLITEN UND RAUMSCHIFFE [SOLAR RADIATION AS AN AUXILIARY SOURCE OF ENERGY FOR SATELLITES AND SPACE VEHICLES].
Hermann Oberth-Gesellschaft, Mitteilunge, 2:155-164, Nov.-Dec. 1965. In German.

Examination of the possibilities of utilizing solar energy for the power requirements aboard satellites and space vehicles. The main problem in any system designed to harness solar energy is conversion efficiency. The efficiency of thermal conversion is determined in part by the degree of precision with which the mirror for capturing solar radiation is constructed. A graph illustrates the comparative efficiencies of balloons, parachutes, deployable structures, segmented mirrors, and metal mirrors, respectively, in order of increasing efficiency.

430. Martin, O.
GEGENWARTIGER STAND DER BEMUHUNGEN UM DIE SONNENSPIEGEL FUR RAUMSTATI NEN UND RAUMSCHIFFE [PRESENT STATE OF EFFORTS IN DEVELOPING THE SOLAR MIRROR FOR SPACE STATIONS AND SPACECRAFT].
Astronautik, 4:2-13, Jan.-Feb. 1967. In German.

Examination of present capabilities for employing solar mirrors to provide auxiliary energy for space vehicles. Concentrators of parabolic shape with precise geometrical accuracy and high reflective efficiency are required to harness the energy of the sun properly. Methods of evaluating and testing solar-power-plant components are described.

431. Mason, J. F. and Wolff, M. F.
MISSILE AND SPACE ELECTRONICS.
Electronics, 34:87-118, illus., Nov. 17, 1961.

Power generation (solar, nuclear and chemical) is discussed on p. 106-107. A figure depicts estimated electric power requirements.

432. Massie, L. D.
ADVANCED SOLAR CELLS.
Space/Aeronautics, 42:60-65, Sept. 1964.

Discussion of flexible, lightweight, thin-flim solar cells.

433. May, J. R.
THE EFFECT OF ENVIRONMENT ON THE DESIGN OF A SOLAR CONCENTRATOR.
In Institute of Environmental Sciences. Proceedings 1960, p. 419-424, Mt. Prospect, Ill., The Institute, 1960.

The use of solar energy for space vehicles is the primary subject.

434. Mayer, S. E. and Ritchie, I. M.
THE USE OF HIGH TEMPERATURE THERMOELECTRIC MATERIALS (SILICIDES) FOR POWER GENERATION IN SPACE.
Paper presented at the ARS Space Power Systems Conference, Sept. 27-30, 1960, New York, American Rocket Society, 12 p. (Paper 1279-60.)

This paper discusses the possible use of some developmental high-temperature thermoelectric materials - the silicides - for space applications. Calculations of efficiency and power-weight ratio are carried out for present typical materials and materials which might reasonably be expected to result from present work. It is shown that even though these materials leave a lot to be desired in terms of efficiency, the power-weight ratios are more favorable than other materials industrially available.

435. Mayo, K. E.
AN EVALUATION OF PRIMARY ELECTRICAL POWER SUPPLIES IN THE ONE TO TEN WATT RANGE FOR LONG TIME REMOTE UNATTENDED TERRESTRIAL USE.
From Institute of Electrical and Electronics Engineers Region 3 Annual Meeting and Technical Conference, Clearwater, Fla., May 1964. 18 p.

The following nine classes of energy converters are evaluated on the bases of size, weight, reliability, relative cost including handling and storage, and availability: Seebeck generators, chemical fuel cells, Nernst generators, magneto-hydrodynamic or plasma generators, thermionic generators, photoelectric generators, batteries, electromechanical generators, and biochemical and bioelectric generators. It is concluded that electrochemical fuel cells and thermoelectric generators compete for optimum selection within the specified constraints. The disadvantage of fuel cells is that fuel is bulky and heavy compared to isotopes; however, when shielding for isotopes is considered, the choice may be marginal.

436. McClelland, D. H.
DEVELOPMENT OF A CONCENTRATING PHOTOVOLTAIC POWER GENERATOR.
New York, American Rocket Society, 1962, 13 p. (ARS Preprint no. 2497-62.)

The power output of a solar cell panel can be increased by the use of auxiliary reflectors or other types of optical concentrating devices. The use of concentration with solar cell systems is discussed and is contrasted with the situation for high temperature solar power converters involving heat engines. Theoretical performance and weight estimates are given for various configurations of concentrating photovoltaic systems. Design and selection of components and materials are discussed, including cells, cell panels, concentrators, filters, and coatings. A 50-watt ground test model is described and experimental performance results are given.

437. McClelland, D. H., Springer, L. M. and Stewart, D. E.
LARGE ALL-METAL SOLAR CONCENTRATORS FOR SPACE POWER SYSTEMS.
New York, American Institute of Aeronautics and Astronautics, 1964, 12 p. (Paper 64-457.)

Discussion of the design of lightweight, accurate, highly reflective solar concentrators for large solar-dynamic electric power systems for space vehicles. Folding petal mirrors up to 50-ft diam. and one-piece mirrors up to 30-ft diam. are considered. The various power conversion cycles are discussed. Required concentrator diameter is given as a function of system power level and power conversion efficiency. Design problems of large furlable concentrators and one-piece concentrators are discussed, including booster weight capability, allowable payload volume and envelope, accuracy and reflectance requirements, and reliability considerations. Design features of 20-ft and 30-ft diam. one-piece mirrors and a 45-ft furlable mirror are described, including performance, structural integrity, weight, packaging techniques, fabrication methods, and reliability.

438. McClelland, D. H., Pichel, M. A. and Springer, L. M.
SOLAR CONCENTRATOR DEVELOPMENT FOR SPACE POWER SYSTEMS.
Institute of Electrical and Electronics Engineers. Special Publication S-45, 102-115, Feb. 1963.

Three types of light weight solar concentrating mirrors which represent different structural concepts are described along with experimental performance results that are compared with calculated performance for idealized reflectors; discussion of mirror testing methods.

439. McClelland, D. H.
SOLAR CONCENTRATORS FOR HIGH TEMPERATURE SPACE POWER SYSTEMS.
In Snyder, N. W. ed. Space Power Systems, p. 129-152, figs., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 4.)

Basic problems in the development of light-weight, high efficiency, solar concentrating mirrors for space power systems are discussed.

Also issued as ARS Paper 1314-60.

440. McClelland, D. H.
SOLAR-MECHANICAL POWER SYSTEMS LOOK GOOD FOR EARLY SPACE FLIGHTS.
Space/Aeronautics, 34:131-132, 135, 140, 144, 146, 150, 154, figs., Nov. 1960.

The combination of dynamic heat engines and electric generators today offers the only practical possibility for a space power system in the 1-20-kw range, it is claimed. Here is a report on the basic design and performance characteristics of such systems.

441. McCusker, T. J.
PARAMETRIC DESIGN STUDY FOR A 1500 WATT SOLAR THERMIONIC ORBITAL POWER SYSTEM.
Los Angeles, Calif., Institute of Aeronautical Sciences, 1964. 14 p. (Paper 62-118.)

Description of a thermionic orbital power system consisting of the following components: (1) solar thermionic generators, (2) orientation systems for alignment of the generators with the Sun, (3) storage batteries for use in the shaded portions of the orbit, (4) power regulators for both battery and system load, and (5) a generator deployment system. The performance characteristics of each component are determined, and are used to establish the energy and power balances of the system.

442. McGuire, F. G.
NASA SPACE LAB PLANS OUTLINED.
Missiles & Rockets, 5:24-26, June 22, 1959.

Solar thermoelectric systems were among the promising auxiliary power systems for space vehicles considered at the American Rocket Society's 1959 semi-annual meeting.

443. McIlroy, W. and Kunen, A. E.
MHD APPLICATIONS FOR SPACE AND GROUND POWER.
International Congress and Exposition of Automotive Engineering, Jan. 9-13, 1961, Detroit, Mich. New York Society of Automotive Engineers, 1961, 21 p. (Preprint 312B.)

Discussion of working problems of pulsed plasma generators, and of the importance of specific impulse and energy conversion efficiency in the selection of a working engine. The development of the plasma pinch engine is presented as an example of an accelerator in the development stage. The application of MHD to electrical generation is described briefly. A short description is also given of analytical work that has been done on the application of a magnetic field to a high power thermionic converter to increase its efficiency.

444. McJones, R. W. and Bass, W. A.
DYNAMIC ENGINES VERSUS FUEL CELLS FOR SPACE POWER SYSTEMS.
Los Angeles, Calif., Institute of Aeronautical Sciences, 1962, 11 p. (Paper 62-119.)

Study of hydrogen-based power systems utilizing either mechanical engines or electrochemical cells for use in medium-duration space missions. The results indicate that straight hydrogen expansion utilizes waste heat but involves large propellant storage volume; either electrochemical or mechanic equipment are believed to be more practical. Stoichiometric hydrogen/oxygen engines offer minimum propellant weight and volume, but require radiators for heat rejection, as does the fuel cell. Stoichiometric engines and fuel cells differ primarily in their fixed weights. Fuel-rich hydrogen/oxygen cycles eliminate radiators but require additional propellant, and only mechanical engines can presently implement these cycles.

445. McKechnie, R. M., III.
FUEL-CELL-INVERTER/CONVERTER SYSTEM SYNTHESIS.
In Wong, C. M. ed., Space Electronics Symposium; Proceedings of the Joint American Astronautical Society and Aerospace Electrical Society Meeting, Los Angeles, Calif., May 25-27, 1965., p. 1-35 to 1-45. New York, American Astronautical Society, 1965.

Description of the synthesis of a fuel-cell inverter/converter system. A technique for the derivation of the parameters needed for fuel cell synthesis has been developed. Using these parameters it is easy to synthesize the fuel-cell inverter/converter system and study system performance for various conditions. This technique has been used to measure the parameters of a space power system. Test data on the Apollo and Gemini fuel cell power plants are presented, and the adequacy of the parameters used for the synthesis is discussed. An example of a fuel cell inverter simulation is given.

446. McKinnon, R. A.
LITHIUM HYDRIDE ENERGY STORAGE IN SPACE POWER APPLICATIONS.
Institute of Electrical and Electronics Engineers. Special Publication S-145, 13-26, Feb. 1963.

Lithium hydride is shown to be attractive means of energy storage and several of its characteristics are more fully explored; practical problems in employing lithium hydride in hardware development test units are discussed, and energy release test results are given; various methods of energy storage are described and their performance compared.

447. Means, P.
THE SEARCH FOR SPACE VEHICLE POWER.
Missiles & Rockets, 5:22-25, Jly. 27, 1959.

Thermoelectric generators and thermionic converters are briefly referred to as possible sources.

448. Means, D. B.
UNLIMITED POWER.
Carnegie Technical, 25:26-27, Apr. 1961.

Methods of converting solar energy into electrical energy are discussed in terms of their acceptability as space power systems.

449. Meier, D.
SEARCH FOR NEW SOURCES OF POWER.
Science Digest, 50:77-79, Dec. 1961.

A general article directed mainly to the search for low cost power for underveloped areas. Mention is, however, made of the progress in use of solar batteries for space missions, and the advantages of fuel cells.

450. Meier, G.
HILFSENERGIEVERSORGUNG BEI FERNLENKWAFFEN [AUXILIARY POWER SUPPLY FOR LONG-RANGE GUIDED MISSILES].
Flugwehr und - Technik, 27:7-10, Jan. 1965. In German.

Brief survey of the auxiliary power supply required to activate the control and guidance system of a missile. The requirements posed to the control system and its elements, such as electronic receivers, electronic computers, sensors (servos and accelerometers), and the system that uses the signals from these elements to activate the rudders or the jet-deflection nozzle, are outlined. The type of storage batteries used to supply the electrically driven elements, the generators that activate the hydraulic servomotors of the hydraulic system, and the hot-gas servomotors of the pneumatic system are examined.

451. Menetrey, W. R.
SPACE APPLICATIONS OF SOLAR ENERGY.
In Zarem, A. M. and Erway, D. D., eds., Introduction to the Utilization of Solar Energy, p. 326-382, New York, McGraw-Hill Book Co., Inc., 1963.

Discussion of possible space applications of solar-thermal and solar-photovoltaic devices. Considered are space vehicle requirements, solar collector area requirements, and different types of available power systems. Discussed in detail are photovoltaic solar conversion panels, including panel structural characteristics and weight, electrical characteristics, and predicted panel operating capabilities; solar concentrator design, including analyses of an ideal concentrator, and of the effects of reflector surface deviations; and general system design considerations, including theoretical limits on the utilization of solar energy, and various factors associated with efficiency and reliability.

452. Menetrey, W. R.
ESTIMATE OF SOLAR-THERMIONIC SYSTEM PERFORMANCE.
New York, American Institute of Aeronautics and Astronautics, 1964, 27 p. (Paper 64-718.)

Discussion of the general performance expected from a solar-thermionic system in 1970. It is stated that, by that time, it will be possible to have operational solar-thermionic systems in a variety of sizes, depending upon application and effort placed on development. A weight comparison is drawn between photovoltaic panels and solar-thermionics in spacecraft operations which range from Mars to Mercury. It is shown that solar-thermionic systems weight compares favorably with the weight expected for photovoltaics; it is noted that definite weight advantages occur in Sun-probe missions which travel close to the Sun.

453. Menetrey, W. R. and Burns, J. D.
A SURVEY OF POWER SYSTEMS FOR SPACE APPLICATION.
In Conference on Space Technology, Dallas, Tex., April 11-13, 1960. Papers. Electrical Engineering in Space Technology, p. 56-66, New York, American Institute of Electrical Engineers, Dec. 1960.

Design characteristics and problem areas associated with some important solar power system components are emphasized. A general discussion is included regarding the power levels at which each system will be useful. Components and subsystems discussed in detail include photovoltaic cell arrays, the solar concentrator used in high temperature thermal systems, the absorber used for absorbing solar radiation and the thermionic diode.

454. Menke, H. H. and Schmidt, E. F.
ISOTOPE BATTERY WITH THERMOELECTRIC GENERATOR.
In Industrial Applications for Isotopic Power Generators, p. 451-459. Paris, European Nuclear Energy Agency, 1967.

The requirements of an isotopic battery are low weight, high reliability, and high efficiency. Low weight can be obtained by the use of aluminum, magnesium, and alloys of these elements for the manufacture of construction parts, and the selection of an isotope fuel such that the weight of the radiation shielding is as low as possible. Reliability and high efficiency are a function of the operational temperature. A high temperature differential of the thermocouples is essential to high efficiency of the thermoelectric converters, and, therefore, results in the most economical use of the isotopic heat source energy. However, a high operating temperature decreases the reliability of isotopic batteries due to decreased material strength to resist shock and vibration damage. An optimum operating temperature condition considering both reliability and efficiency must be obtained. Since the construction of an isotopic battery is already technically solved, the application of such systems is but a question of how the costs of the isotopes can be reduced.

455. Menke, H. and Pegel, K.
STROMVERSORGUNGSSYSTEME MIT FLUSSIGMETALLKREISLAUFFEN [SYSTEMS FOR GENERATING CURRENT WITH LIQUID METAL CYCLING].
Raumfahrtforschung, 9:138-144. Jly.-Sept. 1965. In German.

Discussion of developments in the field of space-power systems using metals in the liquid state as part of a closed cycle. Electrical energy requirements for the larger satellites, space probes, and manned spacecraft are within the 1- to 100-kw range; time requirements are of the order of months to several years. Sources of energy for such systems are chemical, solar, or nuclear. Chemical sources are not suitable for long-term missions because of low specific power output. Solar cells are only adequate for low power requirements due to the limitations inherent on the area of the solar radiation absorbers. Nuclear power systems are most adapted to requirements, using liquid recycled metals such as Li, Na, Mg, K, or Hg as thermodynamic heat exchangers and as coolants. The characteristics and performances of a magnetoplasmadynamic (MPD) and a magnetohydrodynamic (MHD) nuclear power system are described.

456. Merrill, P. S. and others.
SNAP-10 EXPERIMENTAL THERMOELECTRIC GENERATOR.
Advanced Energy Conversion, 2:281-285, Jan.-June 1962.

An experimental thermoelectric generator for the SNAP-10 (Systems for Nuclear Auxiliary Power) power system is described. Preliminary tests results are presented for a unit mounted on an electrical heat source which simulated a nuclear reactor.

457. Mesmeringer, J. C.
ELECTRICAL SOLAR POWER SUPPLY SYSTEM CONSIDERATIONS FOR UK-2/S-52 INTERNATIONAL SATELLITE.

In Annual East Coast Conference on Aerospace and Navigational Electronics, 10th, Baltimore, Md., October 21-23, 1963, Proceedings, p. 1.3.3-1 to 1.3.3-3. North Hollywood, Western Periodicals Co., 1963.

Description from a functional standpoint of the power supply of the UK-2/S-52 satellite. It is stated that the consideration and analysis of environmental and operational requirements, as well as the requirements imposed by the satellite configuration, influenced the UK-2/S-52 power source system design, the detail specifications for the batteries and solar paddles, and the testing of these and associated subassemblies. Also discussed are the load analysis results and some of the performance characteristics of the solar paddles, the main batteries, and the power source control and protective circuits. Significant routines of the test procedures for paddles and batteries, as well as some of the test results, are also dealt with.

458. Metzger, W. H., Jr. and Sherfey, J. M.
ELECTROCHEMICAL CALORIMETRY. III.- THERMAL EFFECTS OF NICKEL-CADMIUM BATTERIES.
Electrochemical Technology, 2:285-289, Sept.-Oct. 1964.

Discussion of calorimetric measurements made during various charge-discharge cycles of nickel-cadmium cells proposed as satellite power sources by NASA. The purpose of the measurements was to determine the heat change involved when the cells were operated at various charge and discharge rates, the problem being directly related to the thermal balance of the Numbus satellite. The electrochemical reactions of three types of sealed nickel-cadmium cells took place in a calorimeter, illustrated and briefly described. Typical curves of heat changes as a function of time during operation are presented and discussed. The heat of reaction of oxygen with the constituents of the cell was measured, and agreement was obtained with the literature value for the heat of formation of cadmium oxide.

459. Miller, B.
NUCLEAR-THERMIONIC POWER UNIT PROPOSED.
Aviation Week, 75:61, 63,665, illus., Jly. 10, 1961.

The powerplant, called STAR (Space Thermionic Auxiliary Reactor), is intended to satisfy the electric power needs of avionic and instrumentation gear of future manned and unmanned space vehicles. The STAR concept envisions a cylindrical power supply comprised of a number of repetitive series-connected rings each containing thermionic diodes, fuel elements, and reflectors. Specific power requirements can be satisfied by adding enough rings to produce the desired power.

460. Miller, B.
THERMIONIC CONVERTER READIED FOR SPACE.
Aviation Week and Space Technology, 76:109, 111, 113, Apr. 16, 1962.

Componets are described of a system called SET (Solar Energy Thermionic Conversion System). Its design falls within an envelope of parameters suitable for an Atlas-Centaur boosted Mariner spacecraft.

461. Miller, D. T. A.
A COMPARISON OF FOUR AUXILIARY POWER SYSTEMS FOR SHORT DURATION MISSILE APPLICATIONS.
New York, Society of Automotive Engineers, 1960, 38 p. (Preprint 232A.)

The four systems compared are: flywheel, silver-zinc battery, solid propellant, and bottled gas. The mission for which the auxiliary power systems (APS) are required is a duty cycle of 100 seconds at an average output of 10 h.p. A detail evaluation of the APS's is carried out and it is concluded that the bottled gas system is unsuitable, the flywheel and solid propellant systems have a good performance under favorable load conditions only, while the battery system is versatile and requires the minimum development time.

462. Milliron, J. R.
NUCLEAR BATTERIES.
Electrical Manufacturing, 56:125-131, Nov. 1955.

Termed also "atomic" and "radioactive" batteries, these power sources convert radioactive isotopes into electrical energy; fundamental principles are reviewed and three basic types of cells, contact potential, solid dielectric, and solid state are described; solar battery.

463. Moncrief, J. L.
FUEL CELLS - A NEW ELECTRICAL POWER SOURCE.
In National Electronics Conference, 22nd, Chicago, Ill., October 3-5, 1966, Proceedings, p. 94-96. Chicago, National Electronics Conference, Inc., 1966.

Survey of the potentials of fuel cells as a low-voltage power source. All fuel cells are now very expensive because of the materials used and the "handmade" type of fabrication and assembly techniques required. Difficult technical problems must be overcome before direct utilization of standard liquid fossil fuels such as gasoline or jet fuel will be practical. However, fuel cells have these advantages: (1) they are not limited by Carnot cycle efficiency; (2) they do not give off noxious fumes; (3) they are almost completely silent; (4) their power density is greater than that of batteries and engine generators for initial weight per kilowatt; and (5) their present high cost can be expected to decrease, as a result of present R and D efforts, to the point where they will be able to compete with special purpose batteries and engine generators.

464. Morasca, N.
LE PILE THERMOELECTRICHE E LE PILE COMBUSTIBILI [THERMOELECTRIC CELLS AND FUEL CELLS].
Rivista Aeronautica, 37:1251-1259, Aug. 1961. In Italian.

Discussion of thermoelectric cells and fuel cells, and of the possibilities they offer as sources of electric power. The operation of thermoelectric cells and of hydrogen-oxygen fuel cells is described, and possible applications to space and surface transport and to electric power stations are noted.

465. MORE ELECTRICAL POWER FOR SPACE.
Aircraft & Missiles, 4:23-29, May 1961.

AEC's SNAP units pack isotope and reactor-type generators and promise abundant electricity for power-starved satellites.

466. Morehouse, C. K., Gliksman, R. and Lozier, G. S.
BATTERIES.
Institute of Radio Engineers, Proceedings, 46:1462-1483, Aug. 1958.

A review of chemical compositions, structures, performance characteristics and applications of various primary and secondary batteries, including nickel-cadmium, zinc-silver oxide and cadmium-silver oxide. Nuclear and solar batteries are also reviewed. There is a bibliography of 108 references.

467. Morgan, K.
THERMIONIC GENERATION.
Institute of Electrical & Electronic Engineers Transactions, E-7; 175-181, Dec. 1964.

This paper discusses the principles of thermionic generators. The characteristics of a thermionic diode are reviewed and an idealized model of a generator is set up. Several ways of overcoming the effects of space charge, the most significant defect of an ideal generator, are considered.

468. Morgulis, N. D.
LE CONVERTISSEUR THERMOELECTRONIQUE (OU CONVERTISSEUR A PLASMA) [THE THERMOELECTRIC CONVERTER (OR PLASMA CONVERTER].
Collection Espace et Electronique. Paris, Gauthier-Villars, 1965. 92 p.

A brief examination is given of the physical principles of the thermoelectric method for the direct transformation of thermal energy into electric energy. Thermoelectron and thermionic emission, space charge and its neutralization, general properties of thermoelectric converters, and some laboratory models and proposed designs of converters are considered.

469. Morse, E. M. and Lawson, D. L.
ZINC-SILVER OXIDE BATTERIES FOR SPACE APPLICATIONS.
In Power Sources Conference, Proceedings, 16th, 1962, p. 127-130, Red Bank, N. J., PSC Publications Committee, 1962.

It has been shown that the silver-zinc primary battery has been fulfilling a large role as a basic power supply for orbiting vehicles during the initial states of space exploration.

470. Morse, J. G.
ENERGY FOR REMOTE AREAS.
Science, 139:1175-1180, Mar. 22, 1963.

Generators fueled with radionuclides are supplying power in small terrestrial and space systems.

471. Morse, J. G. and Fink, C. R.
FROM SNAP 3 TO IMP - THE EVOLUTION OF SPACE ISOTOPIC POWER.
IEEE Transactions on Aerospace, AS-2:642-645, Apr. 1964.

Description of the SNAP's 3, 9A, 11 and the IMP (Interplanetary Monitoring Probe) generators, emphasizing the unique and developmental features of each, as well as those time-tested, operationally successful features which have remained unchanged after close official scrutiny.

472. Morse, J. G. and Harvey, D. G.
ISOTOPIC POWER SOURCES COUPLED WITH THERMOELECTRIC CONVERTERS.
United Nations, International Conference on the Peaceful Uses of Atomic Energy, 3rd, Geneva, Switzerland, May 1964, 15 p. (Paper 28/P/217.)

Discussion of design considerations for SNAP radioisotope-fueled thermoelectric generators for long-term operations. Heat-source fuels and encapsulation materials are reviewed, and typical thermoelectric generator characteristics are described. The use of radioisotope units for space and for terrestrial applications is noted.

473. Morse, J. G. and Harvey, D. G.
NUCLEAR ENERGY IN SPACE -- RADIOISOTOPE AUXILIARY POWER SYSTEMS.
Aerospace Engineering, 20:8-9, 58-62, figs., Nov. 1961.

This new, rugged, compact and reliable device (converting heat to electricity without moving parts) operates independently of solar transients and is adaptable to power needs in space.

474. Morse, J. G.
RADIONUCLIDE POWER SOURCES.
British Interplanetary Society Journal, 19:87-92, May-June 1963.

Reviews the fundamental characteristics of power sources in which the decay heat of a radioisotope is converted into electricity by some direct energy conversion device- a thermoelectric converter in present devices.

475. Morse, J. G.
THE SNAP RADIOISOTOPE POWER SYSTEM.
In Simnad, M. T. and Zumwalt, L. R., eds., Materials and Fuels for High-Temperature Nuclear Energy Applications; American Nuclear Society, National Topical Meeting, San Diego, Calif., April 11-13, 1962, Proceedings, p. 47-59. Cambridge, Mass., MIT Press, 1964.

Brief consideration of some of the unique aspects of the technical problems encountered in the development and use of a SNAP radioisotope power system, emphasizing those design requirements related to the employment of high-temperature materials in such systems. The radioisotope heat power system is briefly described, and the radioisotope heat source is considered. Energy-conversion systems are discussed in terms of thermoelectric and thermionic conversion.

476. Morse, J. G.
SNAP RADIOISOTOPIC POWER SYSTEMS.
Institute of Radio Engineers Transactions, NS-9:34-44, illus., Jan. 1962.

A summary is presented of SNAP radioisotopic power supplies.

477. Moss, T. S.
THE POTENTIALITIES OF SILICON AND GALLIUM ARSENIDE SOLAR BATTERIES.
Solid State Electronics, 2:222-231, May 1961.

The theory of the spectral response of a p-n junction solar battery unit is given, and detailed comparisons are made of the expected performance of silicon and gallium arsenide units.

478. Murphy, J. S.
CASE FOR RELIABLE MISSILE BATTERIES.
Missiles & Rockets, 1:106, 108, 110-112, illus., Dec. 1956.

Requisites of missile power sources; some typical discharge rates of storage batteries in missile applications; specific weights and volumes of missile batteries; and brief descriptions of the most important and practical systems under study and development. These include primary system ((one-shot application) silver-zinc, water-activated, mercury-cell and common dry cell); secondary systems ((rechargeable)-silver-zinc; lead-acid; nickel-cadmium); and silver-zinc system, either primary or secondary, which is said to be superior to others in missile applications because of weight, volume and electrical behavior.

479. Nash, H. and Luft, W.
IMPROVED SILICON PHOTOVOLTAIC CELLS.
Electronic Industries, 18:91-95, Aug. 1959.

Improved process for manufacturing of silicon solar cells described which offers high conversion efficiency and cell construction that

permits reliable mounting. Electrical characteristics of cells are given, and data for solar cell design in space environments and temperature control presented.

480. Naymark, S.
NUCLEAR POWERPLANTS FOR SPACE-VEHICLE APPLICATION.
In American Astronautical Society. Advances in the Aeronautical Sciences. Proceedings, 6th, New York City, 1960, p. 643-658, New York, MacMillan, 1961.

This paper addresses itself basically to the potential place of nuclear energy powerplants for space power applications and to their advantages or disadvantages as compared with other types of powerplants.

481. Neubert, W. E.
SEA WATER BATTERY AUTOMATIC FLOW REGULATION VALVE.
U. S. Patent 3,154,040, July 6, 1962, (to The United States of America as represented by the Secretary of the Navy).

An underwater electrically propelled missile comprising a sea water battery for supplying electrical power to the missile, a closed loop sea water conduit system connected to said battery for directing sea water from the sea through the battery and then returning to the sea, a flow regulation control valve placed within said conduit system having a bypass for permitting a pre-determined minimum flow of sea water through said valve, a moveable spring biased flow restricting means slideably connected to said valve and being positioned to receive dynamic forces imparted by the sea water flowing through said valve, whereby said flow restricting means is displaced by the dynamic forces to regulate between a predetermined maximum and said predetermined minimum the flow of sea water through said valve in direct proportion to the dynamic force exerted by said sea water on said flow restricting means. (U.S. Patent Off.Off.Gaz., 807:885, Oct. 27, 1964.)

482. NEW FUEL CELL FOR SPACE.
Missiles and Rockets, 11:11, Aug. 13, 1962.

Refers to the development of a unique solid-state fuel cell for generating electric power in space. Such a fuel cell requires no pastes or liquid chemicals to produce its chemical electricity.

483. NEW METHODS OF ELECTRIC POWER GENERATION. NO. I.
Engineering, 210:84-86, illus., Jly. 8, 1960.

Reports the investigation of four unusual methods of electric power generation, employing fuel cell, thermoelectric, thermionic and magnetohydrodynamic generating principles, respectively. While none of these methods has so far reached large-scale application in

central power stations, they already are finding important uses in special fields, such as portable power generators for the armed forces and electrical energy sources for missiles and other space vehicles.

484. Newton, J. S.
HOW TO SELECT POWER SYSTEMS FOR AEROSPACE APPLICATIONS.
New York, Society of Automotive Engineers, 1960, 12 p. (Preprint 232D.)

A very generalized discussion of factors affecting the selection of auxiliary power systems for use in aircraft and space vehicles.

485. Ningard, E. R. and Banks, H. O.
ELECTRICAL GENERATION BY DIRECT CONVERSION USING ISOTOPES.
Nuclear Science & Engineering, 2:151-152, June 1959.

Isotope-powered generators present an attractive method of converting decay heat of radioisotopes into useful electric power. Strontium-90 and lead tulluride have been chosen for the power sources and thermoelectric materials. Two studies are reported; one covering a 100-w design for land or sea application and the other a parametric study of space power applications for optimization of conditions. To provide 2000 watts of thermal power, 15 kg of Sr^{90} will be employed as a strontium titanate-chromium cermet. The present design consists of seven strontium titanate cylinders with cladding placed in a circular arrangement in a cylindrical block, which serves as the heat source.

486. Nolan, R. M.
SUN TO COOL SPACESHIP ELECTRONIC COMPONENTS.
Missiles and Rockets (News and Bus, ed), 4:39, 41, illus., Oct. 13, 1958.

Work in progress indicates that it is possible to construct a thermoelectric solar converter which is comparable in efficiency with the silicon solar cell under free space conditions. The thermoelectric converters could be used with concentrators to increase their efficiency resulting in increased utilization of power from the sun.

487. North, N. B.
PREDICTING THE PERFORMANCE OF SOLAR CELLS IN SPACE.
Space/Aeronautics, 37:77-79,81,83, June 1962.

Relationships are reviewed between the essential parameters of solar-cell performance and the changes in cell temperature, incident illumination, and solar-energy spectrum as one goes from lab conditions to space. A method is given for constructing monographs for conversions from sea level characteristics to determine cell performance in spacecraft.

488. NUCLEAR-THERMOELECTRIC GENERATOR DEVELOPED.
Electrical Engineering, 80:392, May 1961.

Refers to a completely portable nuclear auxiliary power device, which weighs less than 40 pounds, produces approximately 150 watts of electric power and is designed for one year of continuous unattended operation. It uses radioactive isotopes, such as Curium 242 as its heat source. It is designated the NAP-100.

489. Nuyts, J. and Goullin, J. P.
UTILISATION DES ISOTOPES DANS L'INDUSTRIE SPATIALE [UTILIZATION OF ISOTOPES IN THE SPACE INDUSTRY].
Revue Francaise d'Astronautique, p. 212-221, Dec. 1966. In French.

Discussion of the criteria of selection of different radioisotopes for use in space science. Invariant characteristics and characteristics which can be improved are reviewed. The properties of the different isotopes selected are tabulated. Possible space applications include the production of electric energy.

490. O'Brien, J. F.
ISOTOPIC POWER SOURCES.
In Hoehn, A. J., ed., Institute of Electrical and Electronics Engineers, 1966 Region Six Annual Conference, Tucson, Ariz., April 26-28, 1966. Papers, vl. 2, p. 587-597. Tucson, Ariz., Conference Record Committee, 1966.

Outline of the accomplishments of the Subsystem for Nuclear Auxiliary Power (SNAP) radioisotopic thermoelectric generator (RTG). These RTGs have been used in all environments currently of interest to man, both as electrical power sources for spacecraft and deep sea beacons and as the vehicle used to pioneer the safety of nuclear power in space.

491. O'Connor, J. J.
ENERGY SYSTEMS IN SPACE.
Power, 106:57-64, illus., Apr., 1962.

Auxiliary electric power applications are mentioned with a comparison of today's silver-zinc cells with increased needs of future space flights. Nuclear energy appears most practical source.

492. Ogburn, G. H., Jr.
NUCLEAR ENERGY POWER SOURCES.
In Power Sources Conference, Proceedings, 14th, 1960, p. 12-18, Red Bank, N. J., PSC Publications Committee, 1960.

The applications of small lightweight nuclear power sources for operation without maintenance for long periods of time in remote areas are discussed. Such sources cost and weigh less than conventional

chemical batteries. The SNAP program, which is developing several devices under 1 kw(e) output, is described. SNAP 10 is a reactor energy source giving 0.3 Mw(e) output from U^{235}-Zr hydride fuel, and is a static compact unit with no cooling system. Some of the possible isotopes for use in radioisotope energy sources and their characteristics are given. SNAP III is fueled by Po^{210} whereas SNAP 1A is fueled by Ce^{144} and is designed for use in space. Other radioisotopic units being developed are briefly described, e. g., thermionic units and units utilizing a long-lived radioisotope (Sr^{90}).

493. Ogburn, G. M.
SNAP-3 - A RADIOISOTOPE-FUELED THERMOELECTRIC GENERATOR.
In Tabanera, T. M, ed., Advances in Space Research; Proceedings of the First Inter-American Symposium on Space Research, Buenos Aires, Argentina, November 1960, p. 411-416. Oxford, Pergamon Press, Ltd; New York, MacMillan Co., 1964.

Description of a proof-of-principle device for converting the heat from radioisotope decay into useful electrical power. Fueled with 2100 c (0.48 gm) of polonium-210, the 4-lb demonstration unit delivers 4.0 watts of electricity and can deliver roughly 10,000 watt-hours over a period of 280 days. The principle of operation (employing the Seebeck effect to convert the heat generated by radioactive disintegration into electricity) is described, and details of the SNAP-3 containment structure and the thermoelectric assembly are given.

494. Oldekop, W. and Budnick, D.
DIE BEDEUTUNG DER KERNENERGIE FUR DIE RAUMFAHRT [SIGNIFICANCE OF NUCLEAR POWER FOR SPACEFLIGHT].
In Blenk, H. ed., Scientific Association for Air and Space Travel and German Association for Rocket Technology and Space Travel Research, Annual Meeting, Berlin, West Germany, September 14-18, 1964, p. 437-443, Braunschweig, West Germany, Friedrich Vieweg und Sohn, 1965. In German.

Review of the basic principles and present development of nuclear-power systems applicable to spaceflight. Three types of system - isotope batteries, energy-source reactors, and nuclear drives - are considered. It is noted that, in isotope batteries, radioisotopes act as heat sources for thermoelectric or thermionic generators. Characteristics of several isotopes are compared tabularly, and the SNAP radioisotope systems are discussed. Energy-source reactors are those used with thermoelectric, turboelectric, or thermionic energy converters as energy sources for electric propulsion systems. Nuclear drives are those in which nuclear reactors are used in place of chemical combustion chambers, for rocket-propulsion systems. It is noted that nuclear power probably has an important role to play in spaceflight.

495. Oman, H. and Street, G., Jr.
EXPERIMENTAL SOLAR THERMIONIC CONVERTER FOR SPACE USE.
Electrical Engineering, 79:967-972, illus., Dec. 1960.

A high-pressure cesium-vapor thermionic converter appears to be promising source of power for space vehicles. On the basis of an analysis described in this article, it was found that a converter with cathode temperatures of 3000 to 3500 degrees Rankine will result in low system weight and high overall efficiency.

496. Oman, H.
SOLAR MACHINES IN SPACE.
Industrial Research, 3:62-69, Oct. 1961.

Survey of recent research and technological advances in the conversion of solar energy to electric power. Several approaches to the design and construction of sunlight concentrators for space use are discussed, as are some promising concepts for energy-conversion plants.

497. Osborn, G. A. and Salmon, T. W.
APPLICATION OF THE ELECTROMAGNETIC GENERATOR TO SPACE POWER SYSTEMS.
IEEE Transactions on Aerospace, AS-2:857-866, Apr. 1964.

Description of a converter of the solid rotor inductor alternator type which makes it suitable for space power applications. The manner in which space power requirements are met by induction features is defined. The effects of space power requirements on the electromagnetic nature of the machine are reviewed, and certain power quality trends are projected. The specific aspects covered are: the solid rotor converter, including the principles of operation, comparison of the inductor and Lundell, radial and axial air gap inductor alternators, and comparison of the latter; environmental conditions; losses, forces, and torques, such as pole face losses, armature conductor losses, magnetic forces, and electromagnetic torques; electrical output, covering power quality, excitation and regulation, and frequency.

498. Osborn, G. A.
DESIGN OF ULTRAHIGH SPEED ALTERNATOR SYSTEMS FOR MOBILE POWER.
IEEE Transactions on Aerospace and Electronic systems, Suppl. AES-2: 103-105, Jly. 1966.

To meet the demand for lightweight mobile power, turboalternator sets can be operated at ultrahigh speeds approaching 100,000 rpm. The high-frequency alternator output is converted by static devices to standard ac frequencies and/or dc power for utilization. This paper describes the design of brushless alternator systems for such applications. The particular suitability of the homopolar inductor generator is cited. Special features are described, including methods of limiting pole face losses, windage and other losses. The operating conditions require particular attention to material selection. Interface problems between the alternator and turbine are also discussed.

499. Osgood, C. C. and Winkler, S. H.
OPTIMIZING THE DESIGN OF A SOLAR POWER SUPPLY SYSTEM.
In Advances in Astronautical Sciences, vl. 6, p. 607-620, New York, American Astronautical Society, distributed by Plenum Press, 1961.

This paper presents all the known significant parameters influencing a solar power supply design and shows how they can be integrated to yield an over-all design which is optimized for total weight and volume.

500. Osmun, W. G.
SPACE NUCLEAR POWER - SNAP-50/SPUR.
Space/Aeronautics, 42:38-45, Dec. 1964.

Description of project intended to demonstrate the feasibility of a lightweight, high-output nuclear electric system for space auxiliary power and electric propulsion.

501. OXYGEN FUEL CELL SYSTEM FOR SPACE VEHICLES.
New York, American Rocket Society, 1962, n. p. (Paper 2560-62.)

An attempt is made to show how hydrogen-oxygen fuel cells are integrated into an optimum powerplant for a space mission. Cell performance parameters are also discussed. The Hydrox cell, which employs hydrogen and oxygen reactants, dual porosity nickel-nickel oxide electrodes, and aqueous potassium hydroxide electrolyte is considered.

502. Palmquist, N. B.
SATELLITE AUXILIARY POWER SYSTEMS.
In Planetary and Space Science, vl. 4, Proceedings of the Fourth AFBMD/SRL Symposium. Advances in Ballistic Missile and Space Technology, p. 202-225, New York, Pergamon Press, Jan. 1961.

General requirements of auxiliary power systems are presented. Preliminary studies, design approaches, and hardware development of the prime energy equipment and power conversion equipment are discussed. The auxiliary power system is formulated, and its flight performance is evaluated. A brief look at future systems such as solar photovoltaic, nuclear, thermoelectric, and high energy batteries is also presented.

503. Pasciutti, E. R.
SOME RELIABILITY/EFFICIENCY ASPECTS OF LOW INPUT VOLTAGE INVERSION/CONVERSION FROM RADIOISOTOPIC THERMOELECTRIC GENERATOR POWER SOURCES.
IEEE Transactions on Aerospace and Electronic Systems, AES-2, Suppl.: 458-465, Nov. 1966.

The transistor component failure possibilities due to voltage and power stress conditions existent in low input voltage inverters when

energized by a radioisotopic thermoelectric generator source (RTG) have been investigated in depth. Circuitwise, it is shown that a properly designed current feedback driven inverter is inherently failsafe with respect to output overload when supplied from a power limited source. An RTG no-load overvoltage protection technique recently developed and described herein offers low dissipation external to the RTG source output power terminals. This is important for spacecraft applications, because it enables a reduction of radiator requirements needed for heat rejection.

504. Pearcy, C.
HIGH VOLTAGE GENERATION FROM PIEZOELECTRIC CERAMIC.
Electronic Engineering, 37:656-659, Oct. 1965.

Outline of the various design techniques needed to fabricate a system of production of high-voltage impulses, based on the direct conversion of mechanical energy to electrical energy, through the use of recent developments in piezoelectric materials. The principle has been exploited in the production of spark generators incorporating lead zirconate titanate (PZT) ceramic cyclinders. Devices of this type have been successfully adapted for the ignition of various gas appliances, missile impact fuses, and for low current, high voltage power supplies. Design equations are listed and explained together with the relevant physical characteristics of PZT ceramic material.

505. Peattie, C. G. and Others.
FACTORS INVOLVED IN THE USE OF A HIGH-TEMPERATURE FUEL CELL AS A SPACE POWER SOURCE.
New York, American Rocket Society, 1962, n.p. (Paper 2565-62.)

Potential advantages of using a high-temperature, molten-electrolyte fuel cell as a space power source are discussed.

506. Pedersen, E. S.
NUCLEAR ENERGY IN SPACE.
Englewood Cliffs, N. J., Prentice-Hall, Inc., 1964. 516 p.

An attempt is made to bring together the broad range of information that falls under the scope of nuclear space power. Some new and unpublished material is included. Included in the subject areas covered are direct power-conversion principles - direct conversion of heat into electricity, various auxiliary power systems for use in spacecraft, nuclear thermionic, thermoelectric and MHD systems, and the basic theories and equations governing thermionic and thermoelectric conversion such as Seebeck, Peltier, Thompson effects, and Richardson equations.

507. Pedersen, E. S.
NUCLEAR-THERMOELECTRIC SPACE POWER SYSTEM.
In Annual East Coast Conference on Aerospace and Navigational Electronics, 10th, Baltimore, Md., October 21-23, Proceedings, p. 3.3.4-1 to 3.3.4-6. North Hollywood, Western Periodicals Co., 1963.

Description of a thermoelectric conversion system which uses a nuclear reactor as heat source. The converter and the waste-heat radiator form an integral part, and the system makes use of two liquid-metal loops and a heat exchanger to match the characteristics of a nuclear reactor to those of the thermoelectric generator. A thermoelectric-electromagnetic pump provides a means of circulating the liquid metals in both loops. It is stated that the operating temperatures of the thermelectric materials used in the design are conservative, permitting a lifetime expectancy of several years.

508. Pericart, J.
CYCLES A DEUX PHASES POUR LA CONVERSION M.H.D. A L'AIDE DE METAUX LIQUIDES [TWO-PHASE CYCLES FOR MHD CONVERSION WITH THE AID OF LIQUID METALS]. Institut Francais du Petrole, Revue, 22:313-355, Feb. 1967. In French.

Critical analysis and personal evaluation of the current state of research in the use of two-phase liquid-metal cycles to achieve direct conversion of heat into electricity in MHD converters. The basic theory by which a liquid metal (the MHD conversion agent) is put in motion by direct contact with a hot expanding gas is reviewed. A classification is made of the relatively numerous two-phase systems which have been proposed up to the present time. The thermodynamic aspect of these problems is discussed, and a theoretical and experimental examination is made of the various elements of which the two-phase cycles are composed, in particular, the liquid-metal MHD generator. Future prospects for two-phase liquid-metal-cycle MHD conversion are evaluated, including the possibility of such conversion in spacecraft power plants and in large power plants on the ground.

509. Perry, L. W.
NUCLEAR REACTOR-THERMIONIC SPACE POWER SYSTEMS.
Paper presented at the ARS Space Power Systems Conference, Santa Monica, Calif., Sept. 27-30, 1960. New York, American Rocket Society, 1960, 8 p. (Paper 1339-60.)

Thermionic power conversion was applied to space power systems by locating cells internal and external to the reactor. The cells may be wrapped about the outer surface of the reactor core or placed inside the reactor, a liquid metal coolant being used to transfer waste heat to an external radiator. The serious limitation to exterior cells is the limited growth potential to higher power levels. When the thermionic cells were incorporated in a reactor, an overall system efficiency of 12% was obtained. Liquid lithium was used as

a reactor coolant. If sufficient cathode life can be obtained, a space power system with a specific weight of 5 to 6 lb/kw(e) at the 300 kw(e) power level is possible.

510. Peschka, W.
ENERGIEVERSORGUNG UND ENERGIEWANDLER IN SATELLITEN UND RAUMFAHRZEUGEN [ENERGY SUPPLY AND ENERGY CONVERTERS IN SATELLITES AND SPACE VEHICLES]
VDI Zeitschrift, 109:572-574, 1967. In German.

Discussion of electric power systems for use on space vehicles. The requirements for such a system are outlined and examined in application to such energy sources as fuel cells (particularly the H2-02 cell employing an ion-exchange membrane as the electrolyte), radioisotopes, and nuclear reactors. The current status of energy converters is reviewed, with particular reference to solar cells, electromechanical, thermionic, thermoelectric, and inductive MFD converters.

511. Picquendar, J. E.
THE THERMIONIC CONVERSION OF ENERGY.
Revue Generale Electronique, no. 216, p. 19-25, 1964. In French.

The principles of thermionic conversion are outlined. The design, operation, and performance of a test converter with a pure metal emitter are described. Converters with non-homogeneous emitters are considered. The use of solar radiation and nuclear energy in connection with thermionic converters is discussed.

512. Picquendar, J. E.
LA CONVERSION THERMOIONIQUE DE L'ENERGIE [THERMIONIC CONVERSION OF ENERGIE].
In Marble, F. E. and Surugue, J., eds., Physics and Technology of Ion Motors; Proceedings of a Technical Meeting of the Combustion and Propulsion Panel at the 13th Agard General Assembly, Athens, Greece, July 15-17, 1963. New York, Gordon and Breach, Science Publishers, Inc., 1966, (AGARD-ograph 88). In French.

Discussion on thermionic energy conversion for space use. Principles are reviewed and two types of converters are described - i.e., converters with a pure metal emitter and converters with non-homogeneous emitters. The problem of using solar energy to bring the emitters of thermionic converters to high temperatures is considered, and the use of such converters for the conversion of nuclear energy is discussed. Space projects of the future include solar and nuclear generators.

513. Pierro, J. J. and Phillips, J. E.
INVESTIGATION OF HIGH-FREQUENCY POWER CONVERSION AND GENERATOR TECHNIQUES.
IEEE Transactions on Aerospace, AS-3, Suppl.:411-422, June 1965.

Investigation of techniques concerned with development of efficient and lightweight power conversion units for use with space power systems. Various conversion and power generation techniques are reviewed.

514. Pietsch, A. and McCormick, J. E.
DEVELOPMENT STATUS OF CLOSED BRAYTON-CYCLE SYSTEMS FOR SPACE POWER APPLICATIONS.
In Intersociety Energy Conversion Engineering Conference, Los Angeles, Calif., September 26-28, 1966, Technical Papers, p. 94-120. New York, American Institute of Aeronautics and Astronautics, 1966.

Work in design of Brayton-cycle power systems for space vehicles and significant achievements in the development of major system components and a complete closed loop are discussed. System design studies, component development, and complete power-conversion-loop tests show the Brayton-cycle to be an important candidate for space power-system application.

515. Pietsch, A.
SOLAR BRAYTON-CYCLE POWER-SYSTEM DEVELOPMENT.
New York, American Institute of Aeronautics and Astronautics, 1964, 23 p. (Paper 64-726.)

Description of a Brayton-cycle space power system. The system, which is illustrated, consists of: (1) a solar energy collector; (2) a heat-receiver/storage unit; (3) a recuperator; (4) a combined rotating unit; and (5) a radiator. This is a single-phase working-fluid cycle using inert gas in a closed power-conversion loop. Also shown is a conceptual illustration of a complete Brayton-cycle space power system. The development work performed on heat receivers compressors, turbines, gas bearings, recuperators, and radiators is described.

516. Pitts, J. N., Jr., Margerum, J. D. and McKee, W. E.
PHOTOCHEMISTRY AND SPACE POWER GENERATION.
ARS J, 31:890-896, Jly. 1961.

Discussion of fundamental photochemical principles and processes relative to: (1) photogalvanic solar batteries, and (2) solar regenerative cells. The necessity of intensive fundamental and applied research in these areas is indicated.

Also issued as ARS Preprint 1180-60.

517. Platner, J. L., Ghere, D. P. and Opperthauser, R. W.
CAPILLARY MEMBRANE HYDROGEN-OXYGEN FUEL CELL SYSTEM FOR SPACE VEHICLE APPLICATION.
Institute of Electrical and Electronic Engineers Transactions, AS-1; 874-883, Aug. 1963.

This paper describes the development of a simple, effective method of electrolyte concentration control for the Allis-Chalmers Capillary Membrane fuel cell. The method, designated as Vapor Pressure Control, operates on the change in electrolyte vapor pressure which occurs over an operable range of electrolyte concentrations. Stability of cell operation with the method is shown theoretically and is verified by tests on two four-cell modules for durations up to 113 hours.

518. Platner, J. L. and Hess, P. D.
STATIC MOISTURE REMOVAL CONCEPT FOR THE HYDROGEN-OXYGEN CAPILLARY FUEL CELL.
Chemical Engineering Progress, Symposium Series, 61:299-305, 1965.

A static moisture removal system has been developed as a result of fundamental studies and laboratory tests conducted to determine the vapor-pressure characteristics of the capillary fuel cell. In this system, a desired water-vapor pressure is maintained in the cell through a diffusion membrane associated with each cell. Water will not be evaporated from the cell electrolyte until the electrolyte vapor pressure exceeds the desired value. Above this value, evaporation rapidly increases. This system is being evaluated for space power applications. The system is described, and initial test results are presented.

519. Pogoda, J.
URZADZENIA NAZIEMNE [GROUND INSTALLATIONS].
Instytut Lotnictwa, Biuletyn Informacyjny, p. 11-15, Sept.-Oct. 1965.
In Polish.

Description of the gantry, control console, and electric-power source devised for launching the Meteor-1 meteorological rocket. A schematic diagram of the electrical ground system is included.

520. Ponthus, P.
APPLICATION DE LA MAGNETOHYDRODYNAMIQUE A LA CONVERSION D'ENERGIE. I.
[APPLICATION OF MAGNETOHYDRODYNAMICS TO ENERGY CONVERSION. I].
Entropie, p. 19-26, Jan.-Feb. 1967. In French.

Consideration of the conversion of energy by MHD means, which is the object of theoretical and experimental research concerning both terrestrial and space applications. This procedure does not require any mechanical parts and will in all probability compete with rotating machines used presently to produce high current densities. The involved phenomena require complex studies. The efforts made in France and elsewhere are synthesized, and the ways in which MHD research is conducted are indicated. The general MHD equations are reproduced under integrable form with reference to their application to varied geometries, and under differentiated form in order to allow particularized studies.

521. Ponthus, P.
APPLICATION DE LA MAGNETOHYDRODYNAMIQUE A LA CONVERSION D'ENERGIE. II.
[APPLICATION OF MAGNETOHYDRODYNAMICS TO ENERGY CONVERSION. II]
Entropie, p. 78-85, May-June 1967. In French.

Examination of the simplifications necessary for the convenient application of the MHD equations to the solution of problems with the aid of elementary MHD-converter models. The equations for one-dimensional flows are solved, and the problem of ac electrical energy is considered. The electrical and thermodynamic characteristics of MHD converters are analyzed and compared, and problems related to conduction-type and induction-type ac MHD generators are examined.

522. Porter, R. W., Cambel, A. B. and Kranc, S.
ELECTRODELESS MAGNETOGASDYNAMIC POWER DURING ENTRY.
Journal of Spacecraft and Rockets, 4:813-815, June 1967.

Discussion of a direct energy conversion device that requires no external electrodes. Power is generated by exploiting the torque on the magnet, which acts as the rotating member of a homopolar power generator. This device eleminates the design problems associated with external-electrode devices - in particular, ablation and sheath effects.

523. Powell, R. W.
STATUS OF SNAP-8 ELECTRICAL GENERATING SYSTEM.
New York, American Institute of Aeronautics and Astronautics, 1964, 12 p.
(Paper 64-758.)

Description of the test operation of the SNAP-8 35-kw turboelectric nuclear space power system. Design efforts are directed toward the attainment of 10,000-hr continuous operating life.

524. POWER GENERATION FOR SPACE APPLICATIONS.
Electronics, 27:78-80, Apr. 1954.

A forward looking general article on the generation of hundreds of kilowatts of electrical energy in various locations in space. Thermionic converters and thermoelectric generators utilizing a plasma arm are suggested for high power application.

525. POWER SOURCES FOR SPACE.
Electronic Equipment Engineering, 8:34-36, 38-40, illus., May 1960.

Techniques for converting fuel directly into electricity are described. They are magnetohydrodynamic generator, fuel cell, thermoelectric and thermionic.

526. POWER WITHOUT MOVING PARTS.
Machine Design, 32:24-27, Apr. 14, 1960.

The present status, advantages and forecast for tomorrow for thermoelectric devices, magnetohydrodynamic generators, fuel cells and thermionic generators.

527. Prem, L. L. and Parkins, W. E.
A NEW METHOD OF MHD POWER CONVERSION EMPLOYING A FLUID METAL.
In Magnetohydrodynamic Electrical Power Generation; Proceedings of an International Symposium, Paris, France, July 6-11, 1964, vl. 2, p. 971-984. Paris, European Nuclear Energy Agency, 1964.

New method for converting high temperature heat directly to electrical energy with an MHD cycle employing a metal as working fluid is described. The principal characteristics of this cycle are: (1) energy conversion is direct, requiring no moving mechanical components; (2) operating temperatures can be within practical limits for materials at present available; (3) either nuclear or fossil fuels can be utilized; (4) with nuclear fuel, the same liquid metal can be used as working fluid and reactor coolant. This fluid-metal MHD power conversion system can generate electric power for space.

528. Preusse, K. E. and Shair, R. C.
THERMAL ANALYSIS OF HERMETICALLY SEALED NICKEL-CADMIUM CELLS FOR SPACE APPLICATIONS.
New York, American Institute of Aeronautics and Astronautics, 1964, 12 p. (Paper 64-751.)

Investigation of the variation of the mean thermal conductivity of a nickel-cadmium cell as a function of overcharge current and environmental temperature. The effect of cell geometry on heat transfer rates has also been determined. It is stated that the significance of this investigation is that, knowing the overcharge current and the environmental temperature, it is possible to determine the thermal conductivity and predict the thermal gradient in the cell, and ultimately in a battery. Several cell configurations have been constructed and analyzed both experimentally and theoretically, and the results are said to agree very well. A specific battery design dictated by thermal considerations is the OAO battery. To test the thermal design, a prototype of a 10-cell section of the OAO battery was constructed, put through an electrical routine at heat sink temperatures of $10^{o}F$, $60^{o}F$, $80^{o}F$, and $130^{o}F$ and, in all tests, the maximum thermal gradient from the heat sink to the skin of the cell being charged never exceeded $13^{o}F$. This is said to compare favorably with the calculated gradient of $129^{o}F$.

529. Price, J. C.
FUEL CELL BATTERY - AEROSPACE GROUND EQUIPMENT.
Institute of Electrical and Electronic Engineers Transactions, AS-1: 140-148, Aug. 1963.

This paper is both a description of the equipment and a discussion of design considerations peculiar to test equipment for fuel cell power sources.

530. Prince, M. B.
APPLICATIONS OF SILICON SOLAR CELLS FOR SPACE AND TERRESTRIAL USE.
Acta Electronica, 5:330-340, Jly. 1962.

A review is given of the improvements made on silicon solar cells. These include the reduction of series resistance by means of grids, better spectral response by means of better diffusions, and newer geometries that allow for higher usage of surfaces. Space applications of solar cells require outer space conditions for testing. Special spectral testing conditions are described and the temperature control problem is discussed. Several typical terrestrial applications of uses for solar cells are described. Finally, the future of the silicon solar cell is forecasted.

531. THE PROMISE OF FUEL CELLS AS A SOURCE OF ELECTRIC POWER.
Science Horizons, 33:3-4, Apr. 1963.

In theory, fuel cells are 100 per cent efficient and so should be superior to batteries and conventional engines as soon as cheaper electrodes are developed. These adaptable devices are likely to be used in small power stations, motor vehicles and in spacecraft.

532. PROPOSES NUCLEAR BATTERIES.
Science News Letter, 73:338, May 31, 1958.

Summary of remarks on advantages of nuclear power batteries for satellite and space vehicles given by Harold Zahl at the Symposium on the Possible Uses of Earth Satellites for Life Sciences Experiments, Washington, D. C., 1958.

533. Pruschek, R.
ENERGIEVERSORGUNGSANLAGEN MIT NUKLEAREN ENERGIEQUELLEN [ENERGY SUPPLY PLANTS WITH NUCLEAR ENERGY SOURCES].
In Energy Supply in Space; Deutsche Gesellschaft fur Raketentechnik und Raumfahrt, Symposium, Stuttgart, West Germany, December 8, 1965, Lectures p. 103-133. Munich, Deutsche Gesellschaft fur Raketentechnik und Raumfahrt, 1966 (Fortschritte in der Raumfahrforschung, vl. 2). In German.

Discussion of the nature of nuclear energy sources (radioisotopes, nuclear reactors) in respect to their utilization in energy supply plants in space-flight devices. The characteristics of various energy transformers and the problems of designing these transformers with nuclear heat sources are examined. The present state of the nuclear energy plants and the development trends in this area are considered.

534. Pruschek, R.
THERMIONIKREAKTOREN FUER DIE ENERGIEVERSORGUNG VON RAUMFLUGGERAETEN [THERMIONIC REACTORS AS POWER SUPPLY OF SPACECRAFTS].
Atomkern Energie , 10:327-332, Sept.-Oct. 1965. In German.

Fast and thermal nuclear reactors with incore-thermionic-converters are discussed with respect to their attitude as power supply for space vehicles. Two different fields for application will be distinguished: 1. auxiliary power supply. 2. electric rocket propulsion. Thermal as well as fast thermionic reactor systems may be used as auxiliary power supply. The choice depends on the required power and on the ratio of transportation to fuel cost. As for electric rocket propulsion, fast thermionic reactor systems could be preferable.

535. Purdy, D. L.
SOLAR THERMIONIC ELECTRIC POWER SYSTEM.
Paper presented at the ARS Space Power Systems Conference, Santa Monica, Calif., Sept. 27-30, 1960. New York, American Rocket Society, 1960, 26 p. (Technical Paper 1311-60.)

The theoretical application of vacuum type thermionic converters for a space power supply utilizing solar power is discussed. The characteristics of presently available commercially produced thermionic converters are described, and the integration of these characteristics, with those of other system components, is explained.

Also in Snyder, N. W., ed. Space Power Systems, p. 153-186, New York, Academic Press, 1961.

536. PUTTING NEW SNAP INTO GENERATORS. NUCLEAR-FUELED POWER SYSTEMS ARE PROVING THEIR WORTH IN LAND, SEA AND SPACE USES.
Chemical Week, 97:85-88, Nov. 13, 1965.

This article reviews past research and developments in SNAP devices and discusses the new systems.

537. Radebold, R.
UBER DIE KONSEQUENZEN EINES UMWANDLUNGSPROZESSES MIT EINEM ZWEIPHASIGEN STOFFSTROM [CONSEQUENCES OF A CONVERSION PROCESS WITH A TWO-PHASE MATERIAL FLOW].
In Energy Supply in Space; Deutsche Gesellschaft fur Raketentechnik und Raumfahrt, Symposium, Stuttgart, West Germany, December 8, 1965, Lectures, p. 249-257. Munich, Deutsche Gesellschaft fur Raketentechnik und Raumfahrt, 1966, (Fortschritte in der Raumfahrtforschung, vl. 2). In German.

Discussion of the concept of a liquid-metal MHD converter with multistage thermodynamic drive designed for use as a power source in space vehicles as an alternative to the thermionic converter. The distinguishing features of the converter proposed are the absence of a

mechanical motion of particles and the substitution for electrons of a liquid metal flow that circulates in the system thus providing full utilization of the advantages of a thermal power station. The use of steel permits the construction of a robust unit of simple design in which bearings and seals are not needed.

538. RADIOACTIVE HEAT TO ELECTRICITY.
Chemical and Engineering News, 32:4183-4184, Oct. 18, 1954.

Brief description of an atomic battery which uses the heat from radioactivity to produce electrical energy.

539. Ramirez, P.
THE DESIGN OF MODULAR HIGH FREQUENCY DC-DC CONVERTERS FOR SPACECRAFT POWER SYSTEMS.
In National Electronics Conference, 22nd, Chicago, Ill., October 3-5, 1966, Proceedings, p. 1035-1040. Chicago, National Electronics Conference, Inc., 1966.

Discussion of high frequency design considerations regarding power switching transistors, fast recovery rectifiers, transformers, and power converter circuits. A comparison is made of the weight and efficiency of three high frequency dc-dc converters, each operated at a different frequency. The design tradeoffs, packaging, and thermal considerations are also included. The weight and operating characteristics of the selected 50-kHz, 100-watt, dc-dc converter are presented. It is considered that a substantial reduction in size and weight of power converters can be realized by use of high frequency techniques.

540. Rappaport, P. and Frink, A. M., Jr.
SEALED NICKEL-CADMIUM, SILVER-CADMIUM AND SILVER-ZINC BATTERIES.
In Proceedings 1963 National Winter Convention on Military Electronics, January 30, 31, February 1, 1963. p. 2-10--2-13. Los Angeles, Calif., Institute of Electrical and Electronics Engineers, 1963.

The paper presents the latest "state of the art" on three hermetically sealed rechargeable battery systems and their application as energy storage devices in space vehicles.

541. Rappaport, P.
SOLAR CELLS TODAY.
In Intersociety Energy Conversion Engineering Conference, Los Angeles, Calif., September 26-28, 1966, Technical Papers, p. 404-408. New York, American Institute of Aeronautics and Astronautics, 1966.

Discussion of improvements being made in solar cell capability. Results on solar cell arrays, thin films and radiation resistance are discussed. Other topics discussed include the status of silicon solar and array considerations. The advantages and limitations of solar

power systems are outlined. It is pointed out that recent excellent progress in lightweight array design, improved radiation resistance, and improved CdS efficiency is promising for the future of the solar cell.

542. Rappaport, P.
SOLAR ENERGY CONVERSION.
Signal, 18:50-52, Aug. 1964.

Discussion of the advantages and limiting factors of solar cells. The efficiency of Si, InP, GaAs, CdTe, GaP and CdS as cell materials and the minimum film thickness required for the materials are tabulated. A diagram of the operation of the silicon cell is presented. Lower cost and lighter weights are thought to be the most urgent requirements for future cells. The production of power in remote locations beyond the reach of power lines, and power supplies up to several hundred watts in space explorations, are the most probable uses of the cells in the future.

543. Rappaport, P.
STATE-OF-THE-ART REPORT ON ELECTRICAL ENERGY SOURCES.
Electronic Industries, 24:36-40, 42, 43, 45, 46, 48, 49, Feb. 1965.

Description of means for the conversion of energy into electrical power. Detailed are three specific techniques - solar cells, thermoelectrics, and thermionics - considered to be of particular interest to electronics engineers. These three methods are static and hence have a reliability advantage over fuel cells, dynamic machines, and MHD. Available solar cells are described and new materials currently being considered for their construction are discussed. Thermoelectric conversion is considered, and the SNAP-10A system is described. Thermionic systems, which have the highest efficiencies of any direct conversion means, are also described, and some tentative predictions are made about future applications of these techniques.

544. Ray, K. A.
DESIGN PARAMETERS FOR PHOTOVOLTAIC POWER CONVERSION IN SPACE.
Institute of Electrical and Electronic Engineers Transactions, 66:158-163, May 1963.

Such design parameters as current, voltage, temperature, and intensity dependency for silicon solar cells are listed. Their relationship to the basic photovoltaic theory is given, and methods for establishing the parameters are described. Other subjects covered are: (1) the solar cell physical characteristics and their interaction with mounting substrate characteristics; (2) typical solar cell panel configuration; (3) the thermal balance problem and typical thermal characteristics such as emissivity and absorptivity; and (4) the "state of the art" for power and weight figure-of-merit for space power conversion.

545. Ray, K. A.
FLEXIBLE SOLAR CELL ARRAYS FOR INCREASED SPACE POWER.
IEEE Transactions on Aerospace and Electronic Systems, AES:3-107-115, Jan. 1967.

Discussion of a flexible solar cell concept. The historical background of such devices is briefly considered, a conceptual design is described for a 20-kw array including a weight breakdown, and an existing design effort is evaluated.

546. Ray, K. A. and Winicur, D. H.
A LARGE AREA SOLAR CELL ARRAY.
New York, American Institute of Aeronautics and Astronautics, 1964, 16 p. (Paper 64-739.)

Presentation of the large area solar cell array, a new concept designed to fill the need for a compact, lightweight space power source capable of providing more than 1500 watts of power. It can be launched and deployed in a simple manner and is designed to operate on oriented vehicles in artificial gravity or zero-gravity environments. The system is presented, and the major components are discussed. The force required to extend the solar panels is calculated, and the force available from extensible boom actuators is given. The LASCA performance as a function of solar panel length-to-width ratio, and the amount of acceleration experienced by the array, are shown. The power-to-weight ratio, as a function of power level at a G of 0.2 g, is derived.

547. Raymond, E. T.
HOW SILICON SOLAR CELLS RATE FOR SPACE POWER.
Society of Automotive Engineers Journal, 68:42-44, Aug. 1960.

Advantages and disadvantages of silicon cells as a primary energy conversion device are listed together with illustrations of a solar-photovoltaic power system and models of a silicon-cell solar collector.

548. Reams, J. D.
SPACE-POWER SUBSYSTEMS - DEVELOPMENT STATUS AND OUTLOOK.
In Energy Supply in Space; Deutsche Gesellschaft Fur Raketentechnik und Raumfahrt, Symposium, Stuttgart, West Germany, December 8, 1965, Lectures p. 11-30. Munich, Deutsche Gesellschaft fur Raketentechnik und Raumfahrt, 1966. (Fortschritte in der Raumfahrtforschung, vl. 2).

Assessment of the technological state of the art of space-power subsystems based on combining chemical, solar, isotope, and nuclear-reactor energy sources with static and dynamic energy converters. Quantitative parametric data for the various concepts are derived, and their developmental trends are examined. The quantitative data are used in combination with qualitative considerations to develop

guidelines for selecting the proper space-power subsystem for the power levels required in a specific space mission. Separate treatment is given to energy-limited subsystems (concepts which use an expendable energy source) and power-limited subsystems (concepts using an inexpendable energy source).

549. Reasbeck, P.
SOME ASPECTS OF THE DEVELOPMENT OF FAST-ACTIVATING SINGLE-SHOT ZINC-SILVER OXIDE BATTERIES.
In Proceedings 3rd International Symposium on Batteries, Bournemouth, Hants, October 1962, p. 419-437. New York, MacMillan, 1963.

This paper discussed factors influencing the speed of activation of batteries and describes activation systems. The influence of temperature and pressure on the performance of cell packs is studied.

550. Reed, C. J.
THERMOELECTRIC BATTERIES.
Electrical World, 29:565, 1897.

Various types of thermoelectric generators are summarized.

551. Reichel, R. H.
ALLGEMEINE ENTWICKLUNGEN IN DER RAUMFAHRTTECHNIK BEI TRAGERRAKETEN UND RAUMFLUGKORPERN [GENERAL DEVELOPMENTS IN SPACE FLIGHT TECHNOLOGY PARTICULARLY FOR BOOSTER ROCKETS AND SPACE VEHICLES].
VDI Zeitschrift, 109:559-564, 1967. In German.

Brief survey of recent progress in booster technology, with particular reference to Titan III, Saturn I, ELDO B1 and B2, and the French "Diamant" booster. Some information on launch and ground facilities is included.

552. Reid, W. T. and Edson, A. P.
FUEL CELLS: TOMORROW'S POWER PLANT.
Battelle Technical Review, 11:2-7, illus., June 1962.

Already available for limited earthbound as well as space uses, fuel cells are under intensive study to extend their usefulness as energy sources for industry and the home. Here is a discussion of the most promising types, their status, and potentialities.

553. Resler, E. L., Jr. and Rosenweig, R. E.
MAGNETOCALORIC POWER.
AIAA Journal, 2:1418-1422, Aug. 1964.

Description of a heat engine which uses the temperature dependence of magnetic forces, and a theoretical analysis to predict efficiency and estimate weights to indicate the potential of this system. A

magnetocaloric space power system consists, in large part, of a heat source, heat exchangers, superconducting magnet subsystem, radiator, and working fluid. It is concluded that, on the basis of its low weight, the magnetocaloric system may be competitive with other possible space power systems. Because of the elimination of high-temperature moving parts, the magnetocaloric system offers the possibility of greater lifetime and reliability.

554. Resnick, B. T.
THE CLOSED BRAYTON CYCLE FOR SPACE POWER - AN ASSESSMENT.
New York, American Society of Mechanical Engineers, 1966, 8 p. (Paper 66-GT/CLC-10.)

Investigation of the closed Brayton cycle for onboard generation of space vehicle electric power from solar, isotope, and nuclear reactor energy sources. Some of the more significant advantages and disadvantages of the closed Brayton cycle are outlined. The factors which influenced the selection of this cycle are reviewed. The key power conversion Brayton components to be investigated are described. These include the radial turbocompressor, the axial turbocompressor, the turboalternator, gas bearings, and the regenerator. The gas bearing characteristics are tabulated. The current status of the Brayton investigation effort is reviewed and future planning is considered. It is concluded that with continued success the closed Brayton cycle should ultimately develop into a fully qualified space power system.

555. Reynard, D. L. and Andrew, A.
IMPROVEMENT OF SILICON SOLAR CELL PERFORMANCE THROUGH THE USE OF THIN FILM COATINGS.
Applied Optics, 5:23-28, Jan. 1966.

Discussion of the effect of thin film coatings used in solar cell power systems for spacecraft on overall cell performance. Anti-reflecting coatings are used to increase the amount of useful energy reaching the active surface of the cell. Multilayer interference filters are employed to reject unwanted portions of the solar spectrum to reduce equilibrium temperature and to prevent uv damage. Glass covers are used in conjunction with these coatings for increasing the thermal emittance of the surface. It is noted that direct coating of solar cells remains as the apparent next step in the technology of thin film coatings. It is possible to manufacture solar cells themselves - i.e., a photosensitive p-n junction - using thin-film deposition techniques.

556. Robinson, T. A.
CHOOSING THE ELECTRIC POWER SYSTEM FOR A SHORT RANGE MISSILE.
IEEE Transactions on Aerospace and Electronic Systems, AES-2, Suppl.: 303-309, Jly. 1966.

This paper develops an approach to the selection of an electric power system and the prime internal power source for a short-range missile. Every conference has many papers on the subject of power sources for missiles. They cover such items as batteries, ram air turbines, hot gas driven turbines, and such possible power sources as thermionic, thermoelectric, solar cells. Each of the different sources has a particular field of appropriate application and many of the fields overlap. Papers on the choice of application of these items to power systems are very few. It is primarily the function of the engineer to apply the knowledge and the devices available in order to create an efficient overall operating system.

557. ROCKET'S EXHAUST HEAT IS TURNED INTO ELECTRIC POWER.
Electrical Engineering, 79:170, Feb. 1960.

Refers to RCA's thermionic generator.

558. Rodot, M.
CONVERSION D'ENERGIE SOLAIRE EN ENERGIE ELECTRIQUE ET MECANIQUE - LES PHOTOPILES SOLAIRES [CONVERSION OF SOLAR TO ELECTRICAL AND MECHANICAL ENERGY - SOLAR PHOTOCELLS].
Centre National de la Recherche Scientifique, Journal des Recherches, p. 621-629, Dec. 1964. In French.

An investigation of the different methods which can be used for converting the heat energy of solar radiation into electricity. Semiconductors permit converting luminous energy to electrical energy. The principle of quanta transitions by which a photon is converted to a paired electron-hole is described, including the manner in which the charge carriers are collected by means of a p-n junction. The theoretical efficiency and the factors involved are discussed. The characteristics of French photocells, which will provide on-board energy for spacecraft are given.

559. Rodriguez, G. E.
VOLTAGE CONVERSION AND REGULATION TECHNIQUES EMPLOYED IN THE PRIME CONVERTER FOR THE ANCHORED INTERPLANETARY MONITORING PLATFORM (AIMP) SPACECRAFT.
IEEE Transactions on Aerospace and Electronic Systems, AES-2, Suppl.: 466-476, Nov. 1966.

Description of the major design concepts considered in the development of a dc-to-dc prime converter for the Anchored Interplanetary Monitoring Platform spacecraft (AIMP). This static converter is used to transform the power from the solar array and battery into suitable levels for the instrumentation and experimental electronics. The design chosen incorporates a duty-cycle switching preregulator controlled by saturable reactors, a dc-to-dc converter synchronized at the basic operating frequency of the preregulator, and series-dissipative regulators exhibiting short-circuit protection. A breakdown of the power losses in the preregulator is presented. The procedures followed to achieve a low magnetic field disturbance are described.

560. Roes, J. B.
AN ELECTROMECHANICAL ENERGY STORAGE SYSTEM FOR SPACE APPLICATION.
In Snyder, N. W. ed., Energy Conversion for Space Power, p. 613-622, illus., New York, Academic Press, 1961.

This paper discusses a mechanical energy storage system and describes the characteristics of a typical example for space application which stores energy in two magnetically suspended fly-wheels. The system converts electrical energy into mechanical energy for storage and, after storage, reconverts it for use in the load.

561. Rohrmann, C. A. and Sayre, E. D.
RADIOISOTOPIC SPACE POWER - PROSPECTS AND LIMITATIONS.
New York American Institute of Aeronautics and Astronautics, 1964, 10 p.

Discussion of the bases for selection of radioisotopes for power applications. Comparisons are made with conventional power sources; and compactness, reliability, long useful life, and relatively light weight are seen as the factors making radioisotopes attractive for power production. The characteristics - half-life, specific power and power density, type of radiation, biological hazard, availability, and cost - of radioisotopic heat sources are surveyed. Design, materials, and safety considerations are then studied. The physical properties of the isotopic heat sources are presented in tabular form.

562. Rosa, R. J.
MHD POWER GENERATION.
New York, American Institute of Electrical Engineers, 1962, 12 p. (Paper 29.)

The principles of MHD power generation are reviewed, including basic electrical properties of gases, major loss mechanisms and overall design considerations. Possible space applications and the present status of MHD generators are outlined.

563. Rosemblum, L. and English, R. E.
NUCLEAR-ELECTRIC SYSTEMS IN SPACE.
In Seminar on Advanced Energy Sources, 1958. Proceedings, p. 243-253, Fort Monmouth, N. J., 1959.

Ideas and thoughts are presented on the role of the radiator in space power systems, nuclear turboelectric systems, and nuclear-thermionic emitters.

564. Ross, B.
SOLAR ENERGY CONVERTERS.
Materials Science and Technology for Advanced Applications, p. 431-452, Englewood Cliffs, N. J., Prentice-Hall, Inc., 1962.

A short discussion of semiconductor P-N junctions is given. This will be related to the operation of a photovoltaic device. A method of fabricating a silicon photovoltaic energy conversion device is discussed. Considerations of spectral response and optimization to solar radiation resulting in the development of a solar simulator are described. Special requirements of solar cells operating in earth space are mentioned.

565. Ross, D. P. and others.
A ONE-MEGAWATT NUCLEAR ELECTRICAL POWER PLANT FOR SPACE APPLICATIONS.
In Ballistic Missile and Space Technology, vl. II, p. 373-382, New York, Academic Press, 1960.

The nuclear potassium vapor power system presented offers attractive weight-to-power ratios and is based on design features permitting early development. Component design philosophy is such that in the event of a failure in a section of the power plant, a major portion of the power will remain deliverable. The four rotating machinery packages and the independent condenser-radiators make this possible.

566. Ross, F. Jr.
GUIDED MISSILES.
New York, Lothrop, Lee & Shepard Co., Inc., 1951, 186 p. illus.

This is a generalized account of missile development in Germany, The United States and other lands. Power is mentioned only incidently.

567. Rouklove, P.
STATUS REPORT ON SOLAR THERMIONIC POWER SYSTEMS.
In Szego, G. C. and Taylor, J. E., eds., Space Power Systems Engineering, p. 909-948, New York, Academic Press, Inc., 1966.

Review of research undertaken to advance the technology of solar thermionic power conversion to such a state that it could be considered as an alternate spacecraft power source. It is considered that efforts are necessary in specialized areas such as cesium reservoir and flux control, ceramic-to-metal seals, generator support structures, solar concentrating mirrors, and thermionic converters. To improve performance, surface phenomena related to the thermionic emission, transport phenomena in the plasma region, and material compatibility have been actively studied. Major improvements in thermionic converter performance have been demonstrated - e. g., power densities to 24 watts/cm^2 and life testing beyond 3000 hr. The materials and technology developed also have direct and indirect application to systems which utilize other thermal sources such as radioisotope and nuclear reactors.

568. Ruetschi, P.
IS THE LEAD-ACID STORAGE BATTERY OBSOLETE?
Electromechanical Society Journal, 108:297-301, illus., Mar. 1961.

A few facts and figures are cited concerning exotic power devices, like nuclear batteries, solar cells, thermoelectric and thermionic generators and fuel cells. They may have application in the future but the writer is led to the conclusion that the lead-acid storage battery will not be supplanted for many years to come.

569. RUGGEDIZED SOLAR CELLS FOR MISSILES.
Electronic Industries, 17:132, Aug. 1958.

Hoffman Type "SS" silicon solar cells are developed to withstand extreme environmental conditions encountered in missile launching.

570. Ruka, R.
NEW METHODS OF GENERATING ELECTRIC POWER, HIGH TEMPERATURE FUEL CELLS - A POTENTIAL LARGE SCALE POWER SOURCE.
Mechanical World, 140:324-325, 1960.

The first of a series of articles describing four new methods of generating electric power which have been developed to the state where they appear to hold real promise as power sources for the future. These are the fuel cell, the thermoelectric generator, the thermionic generator, and the magnetohydrodynamic generator. They operate at successively higher temperatures and raise entirely new problems in materials. The possible rewards are great, however - high efficiency, low capital costs, and new possibilities in power generation, storage, and use. The preliminary stages of the work are explained.

571. Russell, C. R.
ELEMENTS OF ENERGY CONVERSION.
Oxford, England, Pergamon Press, Ltd., 1967, 413 p.

A collation of information on energy conversion and the storage of energy is presented in terms of the fundamental thermodynamics that apply to energy conversion by any process. Emphasis is placed on the development of the theory of heat engines, because they are the most important power sources. Descriptive material is given to provide elementary information on all important energy-conversion devices. Following a general discussion of energy, thermal properties and relations are considered. Various heat-engine cycles are described. The roles of chemical energy and electrochemical processes are examined. Attention is given to solar energy, thermoelectricity, thermionic generators, and radioisotope power sources, and the operation of SNAP generators is described. In conclusion, the methods and applications of energy storage are outlined.

572. Sanborn, D. S.
THE DEVELOPMENT OF DEPLOYABLE SOLAR CONCENTRATORS FOR SPACE POWER.
New York, Society of Automotive Engineers, 1961, n.p. (Preprint 425D.)

Description of a foldable, parabolic, 10-ft, solar concentrator having an overall weight of less than 0.4 lb/ft^2. Such a system meets the presently contemplated performance requirements for efficient operation in conjunction with thermoelectric or Rankine-cycle turbine-alternator system.

573. Sanborn, D. S.
FOLDING MIRROR FOCUSES SUN FOR SPACE POWER.
Society Automotive Engineers Journal, 30:74-75, Jan. 1962. (Paper 425D.)

Large-scale, deployable solar concentrators for space power, weighing less than 0.4 lb per sq.ft, can be built using newly developed techniques. A novel deployment system allows the concentrator to be stowed in a cylindrical package having a diameter less than one-fourth and a length less than one-half the diameter of the extended concentrator.

574. Sandelman, S. L. and McJones, R. W.
EVALUATING APU SYSTEMS FOR SPACECRAFT.
Space/Aeronautics, 31:86, 88, 90, 92, 94, 97, illus., Mar. 1959.

The choice of auxiliary power systems for space vehicles is bewilderingly wide -- it ranges all the way from such standbys as the silver-zinc battery to "blue sky" solar and nuclear devices. Which approach is best for which mission? A review of APU systems points the way to the answer to this question.

575. Sanders, L. G.
UNCONVENTIONAL METHODS OF ELECTRIC POWER GENERATION.
Industrial Chemist, 40:137-143, 1964.

Hydrox cells, although using relatively expensive fuel, would be of particular value for space applications.

576. Schmidt, R. N.
EFFECTIVENESS OF SOLAR ABSORBER SURFACES.
Journal of Spacecraft and Rockets, 2:101-102, Jan.-Feb. 1965.

Solar-thermionic, solar-thermoelectric, and solar-dynamic auxiliary power systems for spacecraft require solar absorption on some type of surface. A method for comparing and evaluating such surfaces on the basis of their radiation properties are described.

577. Schuerch, H. and Robbins, W.
CENTRIFUGALLY STABILIZED DEPLOYABLE SOLAR COLLECTORS.
New York, American Institute of Aeronautics and Astronautics, 1964, 16 p. (Paper 64-732.)

Demonstration that rotary deployment and stabilization mechanisms for solar collectors can materially enhance the attractiveness of this mode of space power generation, as compared to competitive schemes.

The problem of controlling the contour of completely non-rigid surface structures by external force interaction and appropriate metric constraints is considered from a theoretical point of view. Solutions involve membrane and filament-net-type constructions for Fresnel-type reflectors deployed, oriented, and stabilized by interaction of centrifugal force and solar pressure. The possibility of vast increases in surface areas for a given collector weight is examined in terms of the specific power characteristics for typical thermodynamic power generating systems. The effects of systems rotation, required for collector stabilization, are briefly examined.

578. Schuh, N. F. and Tallent, R. J.
SOLAR-POWERED THERMOELECTRIC GENERATOR DESIGN CONSIDERATIONS.
Applications and Industry, 45:345-352, illus., Nov. 1959.

This paper presents, in a brief manner, some of the principles and problems which may be expected in applying solar energy to a thermoelectric generator serving a space vehicle and also describes a small solar-powered thermoelectric generator which was constructed to study these problems. Article with same title appears in Elec. Eng. 78:1172-1176, Dec. 1959. Also issued as AIEE. Transactions Paper 59-847.

579. Schuh, N. F.
THERMOLECTRIC POWER SYSTEMS.
Astronautics and Aerospace Engineering, 1:80-83, May 1963.

Against a background of several years of basic studies, and recent progress with available materials, emphasis shifts to the design of practical devices for space systems.

580. Schulman, F., Scott, W. G. and Woodward, W. H.
POWER SUPPLIES.
Space/Aeronautics, 42:101-105, Sept. 1964.

Discussion of static and dynamic solar-power systems, batteries, and fuel cells for use in spacecraft. Silicon solar cells represent the most advanced method available for the conversion of solar energy to electricity. Focused solar energy also can be converted by electromechanical equipment. Several engine cycles have been studied for this purpose, including the Rankine cycle (with mercury, biphenyl, rubidium, and steam as the working fluids), the externally heated Stirling cycle, and the Brayton cycle. A recent development is the third electrode battery, which includes a fuel-cell-type oxygen electrode. It allows the construction of a lighter case with less stress on the seals and a means of determining when charging is complete. Present fuel cells are hydrogen-oxygen units producing about one lb of water per kilowatt-hour of electric energy. Present isotope power supplies use plutonium-238 as the heat source and lead-tellurium thermoelectrics as the conversion system.

581. Schulman, I. M.
SECONDARY BATTERIES FOR ENERGY STORAGE IN SPACE.
In Snyder, N. W. ed., Energy Conversion for Space Power, p. 479-496, figs., New York, Academic Press, 1961. (Progress in Astronautics and Rocketry, vl. 3.)

Certain problems associated with the design of batteries for space applications are discussed. Emphasis is placed on battery-charging problems when using the solar array for energy conversion.

Also issued as ARS Tech, Paper 1307-60, 21 p., New York, American Rocket Society, 1960.

582. Schult, R. W. and Stafford, W. T.
ELECTROCHEMICAL ENERGY SOURCES. SILVER OXIDE/ZINC BATTERIES.
Electro-Technology, 67:84-90, figs., June 1961.

A study of the characteristics and systems design of several types of galvanic power sources for missile and space-vehicle controls and components operation.

583. Schultz, R. L. and Melber, W. E.
BRAYTON CYCLE RADIOISOTOPE SPACE POWER SYSTEM.
New York, Society of Automotive Engineers, 1964, 21 p. (Paper 921B.)

Description of a space power system intended to demonstrate the capability of the closed recuperated Brayton cycle as a heat engine suitable for space application, and to show how radioisotope fuel can be utilized as an energy source for such a system. The system's design and operation, the heat source, the components of the system, and its performance and reliability are discussed. The feeling is expressed that this program has admirably served its purpose in demonstrating the relative ease with which the closed recuperative Brayton-cycle heat engine can be developed.

584. Schwartz, H. J.
FUEL CELLS.
New York, American Institute of Chemical Engineers, 1965, 18 p.

Discussion of the use of fuel cells as spacecraft power systems. A fuel cell may be considered to be an isothermal steady-state reactor in which the conversion of hydrogen and oxygen to water is accomplished. In order to maintain steady-state operation, heat and product removal techniques must be applied to the fuel cell. Three hydrogen-oxygen fuel cell systems are currently under development for aerospace applications. The three are described in terms of their basic operating parameters and construction features. The methods by which each system accomplishes the required heat-and mass-transfer operations are described.

585. Seifert, H. S. and K. Brown.
BALLISTIC MISSILE AND SPACE VEHICLE SYSTEMS.
New York, John Wiley & Sons, Inc., 1961. 526 p., illus.

The engineering design aspects of vehicle mechanical systems are stressed, including power sources.

586. Seiger, H. N., Preusse, K. E. and Shair, R. C.
RECENT BATTERY DEVELOPMENTS FOR AEROSPACE SYSTEMS.
IEEE Transactions on Aerospace and Electronic Systems, AES-2, Suppl.: 61-66, Jly. 1966.

Analysis of data on the cycle life capability of hermetically sealed nickel-cadmium batteries for space power systems. A 100 amp-hr cell with Adhydrode is described, and the systems considerations relating to heat transfer and charge control are discussed. It is noted that this sealed space cell can be rapidly recharged without danger of excessive internal pressure buildup or excessive overheating during overcharge.

587. Shair, R. C., Rampel, G. and Kantner, E.
HERMETICALLY-SEALED NICKEL-CADMIUM AND SILVER-CADMIUM STORAGE BATTERIES.
Institute of Radio Engineers Transactions, MIL-6:67-71, illus., Jan., 1962.

The galvanic battery is the most highly developed means of storing electrical energy today. In space-vehicle applications where auxiliary electrical power is required, it has been found that the most feasible power supply currently available consists of silicon solar cells used in conjunction with sealed nickel-cadmium storage batteries. They are capable of thousands of repeated cycles and have an energy output of about 12 watt-hours per pound. Sealed silver-cadmium cells are of interest because of their higher output 24-watt-hours per pound, but they are not as far developed, nor do they as yet have the cycle life of nickel-cadmium cells.

588. Shair, R. C. and Seiger, H. N.
OPERATING CHARACTERISTICS OF SEALED NICKEL-CADMIUM AND SILVER-CADMIUM BATTERIES.
In Collins, D. H. ed., Batteries 2; International Symposium, 4th, Brighton, England, September 29-October 1, 1964, Proceedings, p. 431-443.

Description of hermetically sealed nickel-cadmium and silver-cadmium fuel cell batteries for aerospace applications. Mechanical considerations for the construction of such batteries are noted. The electrical characteristics of these batteries and the results of life-cycle tests with them are described. Also discussed is the use in sealed cells of an auxiliary electrode for enhanced overcharge capability and for end-of-charge control.

589. Shair, R. C., Lerner, S. R., Joyner, P. A. and Evans, G. E.
A REVIEW OF BATTERIES AND FUEL CELLS FOR SPACE POWER SYSTEMS.
Journal of Spacecraft and Rockets, 4:833-838, Jly. 1967.

Survey of several types of batteries and fuel cells for space power systems. Batteries studied included the mercuric oxide/zinc dry cell, the nickel-cadmium secondary battery (used where high reliability and completely automatic operation are essential for space applications), the silver-cadmium battery (where a high specific-energy capability is desirable and/or nonmagnetic construction is necessary), the silver-zinc primary and secondary batteries (characterized by the highest specific-energy capability), and the zinc-oxygen primary battery/fuel cell hybrid (with energy densities in the 120 to 150 watt-hr/lb), the ion exchange cell, the free-electrolyte fuel cell (gross thermal efficiency about 60% at rated load), and the capillary type cell.

590. Shair, R. C.
SEALED SECONDARY CELLS FOR SPACE POWER SYSTEM.
New York, American Institute of Aeronautics, 1964, 6 p. (Paper 64-455.)

Discussion and evaluation of nickel-cadmium, silver-cadmium, and silver-zinc alkaline battery systems. Various types of mechanical construction are described. Typical charge and discharge curves for the three systems are presented, with more detailed data for the nickel-cadmium system. Overcharge capability, charge efficiency, and charge control are examined. An auxiliary electrode which has recently been incorporated in both nickel-cadmium and silver-cadmium cells for enhancing overcharge capability and providing a signal for charge control is described.

Also in Journal of Spacecraft and Rockets, 3:68-79, Jan. 1966.

591. Sharafi, A. Sh. and Klein, G. A.
FACETED SOLAR ENERGY CONCENTRATORS.
Geliotekhnika, 1:28-30, Mar.-Apr. 1965. Translation. Applied Solar Energy, 1:27-28, Mar.- Apr. 1965.

Description of two types of faceted solar concentrator using a metal reflector, for predicting the aging due to solar radiation of common synthetic materials. The concentrators are considered light, simple to make, and easy to operate, but they cannot give as uniform a flux as a faceted glass-mirror concentrator.

592. Shirland, F. A.
THE HISTORY, DESIGN, FABRICATION AND PERFORMANCE OF CdS THIN FILM SOLAR CELLS.
Advanced Energy Conversion, 6:201-221, Oct.-Dec. 1966.

The history of the thin film CdS solar cell is traced since its first reduction to practice in 1955. The major factors which contributed to the evolution of the present 4-to-8% large area lightweight cell are discussed. Various possible constructions of CdS thin film solar cells are described along with the advantages and disadvantages of each. A brief outline is given of the steps in fabricating the present design high efficiency cell, along with the more important process parameters. The operating characteristics of the best present cells are presented in detail including the effect of light intensity and temperature on the voltage, current and power output, the spectral responses, and the factors affecting cell stability. There is a brief discussion of the possibilities for further improvements in these cells, and a listing of some of their probable applications in space.

593. Shorr, W., Linden, D. and Daniel, A. F.
POWER SOURCES DESIGNED FOR SPACE.
Institute of Radio Engineers Transactions. Mil-4:313-316, Apr/Jly. 1960.

Describes conversion systems employing chemical, solar and nuclear energies and discusses their prospects for further improvement.

594. Shure, L. I. and Schwartz, H. J.
SURVEY OF ELECTRIC POWER PLANTS FOR SPACE APPLICATIONS.
New York, American Institute of Chemical Engineers, 1965, 35 p.

Review of powerplants that are currently under development for space application, including solar cells, batteries, fuel cells, thermoelectric generators, and thermionic, nuclear, and solar-mechanical systems. These svstems are described in terms of their similarities to conventional devices rather than their differences. In almost every case, it can be shown that the concept being used, whether new or old, came into being because of its commercial potentiality rather than space power requirements. The Rankine cycle and the Brayton cycle are discussed. It is pointed out that space power systems are really hybrid devices, being neither exotic systems developed only for space use nor familiar everyday ground-type powerplants. Space power systems represent a logical modification or extension of ground-power technology to meet a special set of operation requirements. The result will ultimately be a general across-the-board improvement or upgrading of all power systems.

595. Siegel, S.
NUCLEAR REACTORS FOR REMOTE SERVICE.
In Hoehn, A. J. ed., Institute of Electrical and Electronics Engineers, 1966 Region Six Annual Conference, Tucson, Ariz., April 26-28, 1966, Papers. Volume 2, p. 577-786. Tucson, Ariz., Conference Record Committee, 1966.

Summary of the scientific and technological features of nuclear reactors which adapt them uniquely for service as power sources in remote locations where fuel supply and maintenance are extremely difficult or impossible after initial startup. The high-energy density of nuclear reactors offers the possibility of unusual compactness, since there is no need for large volumes to store fuel. Examples of situations successfully served by SNAP reactors are given, and future possibilities are assessed.

596. Singer, S. F.
POWER SOURCES FOR SPACE FLIGHT.
Missile & Rockets, 1:82-84, illus., Dec. 1956.

A discussion of the importance of electric power and the utilization of chemical batteries, radioactive and nuclear power supplies. Mercury cell, re-chargeable, fuel-cell and solar batteries are mentioned.

Table I lists the various batteries discussed with an indication of the energy output of their power supply divided by its weight.

597. SNAP'S SEEN TOP SPACE POWER SOURCES BY 1970.
Missiles & Rockets, 7:25, Nov. 7, 1960.

New details of the systems currently under development at Atomics International. These include SNAP 10, SNAP 2 and SNAP 8, in order of increasing electrical output.

598. Snyder, N. W.
POWER SUPPLIES FOR SPACE VEHICLES.
In Proceedings of the International Astronautical Congress, XIth, Stockhlom, 1960, v1. 1, p. 688-713, Vienna, Springer-Verlag, 1961.

This article discusses the power requirements for space, types of power systems (solar-photovoltaic, solar-thermoelectric, solar-thermionic, solar dynamic engine system, solar-photoemission systems, solar regenerative fuel cells, nuclear-thermoelectric, nuclear-reciprocating engine system, chemical turboelectric system and radioisotope-thermionic), weight considerations of space power systems, relation of ground power systems to space power systems, mode of conversion of energy (thermoelectricity, thermionics, dynamic heat engines, pyro-electric effects, photovoltaic cells, photo-electric emission, galvanic cell batteries, and fuel cell batteries), storage of energy, and reliability requirements.

599. Snyder, N. W. and Karcher, R. W.
SOLAR CELL POWER SYSTEMS FOR SPACE VEHICLES.
In Snyder, N. W. ed., Space Power Systems, p. 3-10, New York, Academic Press, 1961.

This paper highlights and summarizes the engineering aspects of a symposium involving solar cell power systems. Silicon solar cells have been the energy converter between solar energy and electricity with the storage of energy being accomplished by the nickel-cadmium battery. The power level of the solar cell system affects two design factors, the stabilization method and the array design.

Also in Institute of Radio Engineers Transactions Mil-6:84-91, Jan. 1962.

600. Snyder, N. W.
SPACE POWER.
In Power Sources Conference. Proceedings, 13th, 1959, p. 2-17, Fort Monmouth, N. J., U. S. Army Signal Research & Development Laboratory, Power Sources Division, 1959.

Missions in space are indicated, power requirements and types are defined, and sources, conversion and storage of energy are discussed.

601. Snyder, N. W. ed.
SPACE POWER SYSTEMS.
A Selection of Technical Papers based mainly on a Symposium of the American Rocket Society held at Santa Monica, California, September 27-30, 1960. New York, Academic Press, 1961. 632 p., illus. (Progress in Astronautics and Rocketry, vl. 4.)

For specific papers see the following author entries: Dieckamp, H. M., Evans, W. H., McClelland, D. H., Perry, L. W., Purdy, D. L., and Snyder, N. W.

602. Snyder, N. W.
STATE OF THE ART - 1962 - POWER SYSTEMS.
Astronautics, 7:110-114, Nov. 1962.

Various possibilities for space power supplies are surveyed. Thermoelectric elements, fuel cells, solar cells, magnetohydrodynamic and nuclear-electric systems are among those considered.

603. Sohn, R. L. and Wheater, H. W.
ENVIRONMENTAL PROBLEMS ASSOCIATED WITH THE DESIGN AND OPERATION OF SPACE VEHICLE POWER SYSTEMS.
In Institute of Environmental Sciences. Proceedings 1960, p. 375-398, illus., Mt. Prospect, Ill., Institute of Environmental Sciences., 1960.

Space vehicle power supply requirements are defined and the nature and capabilities of power systems that can meet these requirements are described.

604. SOLAR BATTERIES FOR SATELLITE.
Army-Navy-Air Force Register, 78:6, June 29, 1957.

Refers to successful operational testing of solar cells attached to the skin of an Aerobee-Hi rocket.

605. SOLAR ENERGY IN THE SPACE AGE.
The Sun at Work, 3:3-4, Dec. 1958.

The work of several agencies is reviwed to indicate the interest in increasing the amount of power furnished by solar cells.

606. Soler, K.
ATOMIC BATTERIES.
Pokroky Matematiky Fysiky a Astronomie, 6:15-23, 1961. In Russian.

The basic principle of atomic batteries, their development, and types are discussed. Maximum performance was attained when a solar light (solar battery) was used instead of radioactive radiation for the excitation of battery emf. Solar batteries were successfully used in the third Soviet satellite. In the US a miniature atomic battery whose energy source is radioactive Pm-147 is discussed; its beta radiation falls on a P layer where it produces light flashes, the light energy is then transformed into electric energy. The battery has the dimensions of a pill.

Also available as Translation no. FTD-TT-61-72, by Air Force Systems Command, Wright-Patterson Air Force Base, Oct. 1961.

607. Solomon, F. and Work, G. W.
PRESENT-DAY LONG LIFE SILVER-ZINC SECONDARY BATTERIES.
In Collins, D. H. ed., Batteries 2; International Symposium, 4th Brighton, England, September 29-October 1, 1964, Proceedings, p. 463-473. Oxford, Pergamon Press, Ltd., 1965.

The silver-zinc battery has been studied to gain a better understanding of its characteristics and to improve its capabilities for secondary battery applications. Factors which limit cell life are discussed as are the effects of cycling regime and certain design parameters. The silver-zinc battery is not generally considered a long-life battery in time or cycles, but it may equal or exceed other batteries of the same size and weight on the basis of total ampere hours discharged because of its high energy density.

608. Somers, E. V.
ENERGY GENERATION AND CONVERSION.
Chemical Engineering, 72:167-174, May 10, 1965.

The present accomplishments in the fields of thermolectricity, thermionics, fuel cells and magnetohydrodynamics are discussed.

609. SPACE POWER NEEDS URGENT. EMPHASIS SHIFTS TOWARD SOLAR-ENERGIZED UNITS: SOLAR MECHANICAL SYSTEMS HAVE TIME EDGE OVER NUCLEAR UNITS.
Missiles & Rockets, 7:22-23, 29, charts, Aug. 15, 1960.

A description is given of a typical solar mechanical power system embodying the following major components and subsystems - concentrator, absorber, heat engine, generator, radiator, energy storage and control and regulated systems.

610. SPACE POWER SYSTEMS.
Electromechanics Design, 4:30-36, Sept. 1960.

A survey of developmental programs being conducted on power systems for future space vehicles.

611. SPACE THERMOELECTRIC UNIT USES SOLAR ENERGY.
Electronics, 34:77, Jan. 20, 1961.

Refers briefly to a solar-energy thermionic conversion device consisting of semiconductor elements sandwiched between light-weight metallic sheets.

612. Spangler, E. R. and Thiel, A. K.
QUELLEN ZUR DECKUNG DES ELEKTRISCHEN ENERGIEBEDARES IN RAUMFLUGKORPERN (SOURCES FOR SATISFYING SPACECRAFT ELECTRICAL POWER REQUIREMENTS].
VDI Zeitschrift, 108:853-857, 1966. In German.

Evaluation of possible power sources for the circuits of an unmanned spacecraft. Solar cells, fuel elements, radioisotopes, turbo-generators, fuel cells, and thermionic generators are among the power sources considered. Energy conversion processes involved are discussed.

613. Stafford, G. B.
LIQUID METAL MAGNETOHYDRODYNAMIC POWER CONVERSION.
In Air Force Systems Command RTD Technology Briefs, 1:2-7, Aug. 1963.

The use of a liquid metal in a MHD conversion channel appears to be an extremely attractive power source for applications requiring long-term, reliable, and unattended operation.

614. Stafford, G. B.
CAPABILITIES OF POWER SUBSYSTEMS FOR SPACE.
Mechanical Engineering, 87:48-53, Sept. 1965.

Assessment of the present state of technology in space electric-power subsystem generation. A distinction is made between energy-limited and power-limited subsystems, and a number of subsystems of both types are discussed, power-limited subsystems being considered both from the point of view of energy sources and energy conversion. A summary is made of the capabilities that can be expected of the various subsystems by 1972.

615. Stafford, G. B.
SPACE POWER SUBSYSTEM CAPABILITIES.
New York, American Institute of Aeronautics and Astronautics, 1965, 16 p.
(Paper 65-468.)

Assessment of the present state of technology in space electric-power generation and projection of the state of this technology through the mid-1970 time period. An investigation is made to determine which power subsystems are presently available for use, and which can be anticipated in 1968 and 1972; combinations of these subsystems are then described which can cover the range of power levels and durations for postulated space systems. It is concluded that although radioisotope subsystems are now unattractive, continuing work on them and increased isotope production will make them both attractive and competitive in the less than 10-kw power range. Also, a general trend exists toward use of static rather than dynamic energy conversion for all but high-power applications.

616. Stambler, I.
THE ATOM AND SPACE.
Space/Aeronautics, 37:60-66, illus., Apr., 1962.

Current aerospace nuclear development programs are reported including the SNAP (systems for nuclear auxiliary power), SPUR (space power unit reactor), and STAR (space thermionic auxiliary reactor) projects.

617. Starkey, G. E.
FUEL CELLS FOR ASTRONAUTIC APPLICATION.
Institute of Electrical and Electronic Engineers, Special Publication, S-145:127-139, Feb. 1963.

This paper presents the requirements, status, and major problem areas of several regenerative fuel cell systems being developed for space applications.

618. Steier, H. P.
SILVER-ZINC BATTERY MAY SOLVE SOME WEIGHT, SPACE PROBLEMS.
American Aviation, 19:44-47, Mar. 12, 1956.

Yardney Silvercell is based on 150-year old system suggested by Volta and developed since World War 1 by French scientist Andre.

619. Stiemel, K.
ADVANCES IN UNCONVENTIONAL ENERGY CONVERTORS.
ETZ, A, 83:844-852, Dec. 1962. In German.

Various aspects of evaluation of unconventional sources are discussed. Reference is made to the temperature-entropy diagram when treating a combined process. A description is given of the working principles and the state-of-art of following energy sources: solar cell, thermo-

electrical convertor, thermionic generator, magnetohydrodynamic generator and fuel cell. Direction of research and possible applications are outlined with special reference to the use in space vehicles and co-operation with high temperature reactors. (Elec. Eng. Abs., 66:6617, Jly. 1963.)

620. Stivers, G.
RADIOISOTOPE THERMOELECTRIC SPACE POWER SUPPLIES.
IEEE Transactions on Aerospace, AS-2:652-660, Apr. 1964.

The weight and efficiency of radioisotope thermoelectric space power supplies, using Plutonium-238, Curium-244 and Strontium-90 fuels, lead telluride and silicon germanium alloy thermoelectric systems, and ranging in power output from 30 to 300 electrical watts are presented. It is shown that there is a definite radiator temperature for which generator weight is minimum and that this temperature varies with fuel, thermoelectric conversion system, and power level. In addition, the various factors governing the selection of a particular radioisotope power supply for a given mission are discussed.

621. Strunk, B.
MINIMUM POWER CONSUMPTION SERVOS FOR SPACE USE.
In Annual East Coast Conference on Aerospace and Navigational Electronics, 10th, Baltimore, Md., October 21-23, 1963, Proceedings, p. 3.3.5-1 to 3.3.5-5. North Hollywood, Western Periodicals Co., 1963.

Description of a general-purpose servo which consumes a minimum of power. It reduces its power consumption at null position by cutting off power on its output power stages. The servo utilizes a stepper motor. A second servo is also described which is used as an output servo for a space-borne digital computer. A technique for reducing power and eliminating stability problems is discussed. It is noted that the circuits can be very low-power-consumption, microelectronic circuits. The power NAND-gate circuits, which are the only high-power circuits in the servo, are switched off at null.

622. Summers, C. M.
ELECTRICAL ENERGY BY DIRECT CONVERSION.
Oil and Gas Equipment, Mar. 1966, 26 p.

Presentation of a series of articles on electrical energy by direct conversion. Insights are provided into developments in this field, their potential as an economic source of electrical energy, and an understanding of the principles involved in the conversion process. Methods are described that are already finding commercial application and whose equipment is on the market. These include the fuel cell, the thermoelectric generator, the solar cell, and the wind-powered generator. Studies and laboratory investigations are being conducted on others.

623. SUNFLOWER IN SPACE: POWER FROM PROVED HARDWARE.
Machine Design, 33:14, illus., Apr. 27, 1961.

Basis of this short article is a statement by C. J. Daye of Thompson Ramo Wooldridge Inc., Tapco Group, to the effect that "auxiliary-power-systems based on the Sunflower concept (hinged 'petals' unfolding to form a parabolic solar collector) may be the most practical first-generation method of producing electricity in space."

624. Sutton, G. W.
MAGNETOHYDRODYNAMIC POWER GENERATION.
In Sutton, G. W. ed., Direct Energy Conversion, p. 181-238. New York, McGraw-Hill Book Co, 1966.(Inter-University Electronics Series. vl. 3).

Consideration of MHD electric power generation, which is based on the concept of using flowing ionized gases or liquid metals as the moving conductor which has been heated by chemical or nuclear fuel. The subject is introduced by examination of the three dc geometries of most current interest. The linear channel and its variations are emphasized. The properties of partially ionized gases are given. The theoretical performance of the linear geometry is derived, including the Hall effect and ion slip. This is first considered for a short section of a dc generators, and includes a discussion of the continuous-electrode, segmented-electrode, and Hall geometries. The performance of the ac induction generator is derived. The factors which affect overall generator efficiency are considered, and general expressions are derived for the polytropic efficiencies of the linear diameters. Compressible flow theory is then applied to the linear geometry in order to obtain expressions for the overall performance. The application of the MHD generator to various cycles is discussed, and experimental results are described.

625. Swenski, D. F. and May, J. R.
ADVANCED CONTINUOUS DUTY POWER SUPPLY FOR SPACE VEHICLES.
New York, American Institute of Aeronautics and Astronautics, 1964, 12 p. (Paper 64-753.)

Discussion of an accessory power unit (APU). This unit, is powered by cryogenic hydrogen and oxygen propellants and delivers approximately 37 hp of combined electrical and hydraulic power at maximum intermittent rated conditions for an operational life of 250 hr. It is stated that the unit has a precise control system and a reliable shaft brake. The integral turbine of Rene 41 is said to be capable of operating more than 250 hours with a 1500°F inlet temperature.

626. Szego, G. C. and Cohn, E. M.
FUEL CELLS FOR AEROSPACE APPLICATION.
Astronautics and Aerospace Engineering, 1:107-111, May 1963.

631. TEST INFLATABLE COLLECTOR FOR SOLAR ENERGY.
Electronics, 33:12, Dec. 23, 1960.

An inflatable solar energy collector is described. The metalized plastic device is meant to be tucked into a canister the size of a coffee cup and lofted into space; once aloft, it inflates to a conical reflector configuration seven feet in diameter at the base.

632. THERMOELECTRIC GENERATOR FOR OUTER SPACE.
Westinghouse Engineer, 19:187-188, illus., Nov. 1959.

A model of a solar-powered thermoelectric generator indicates the system is a practical source of electrical power in space. The concave mirror concentrates the sun's ray on the cylindrically shaped generator.

633. THERMOELECTRIC GENERATOR WITH NUCLEAR BATTERY.
Product Engineering, 29:5, illus., Aug. 11, 1958.

Includes illustration of novel power source designed by Monsanto engineers at the AEC'S Mound Laboratory.

634. SUR UN GENERATEUR SOLAIRE THERMOELECTRIQUE [THERMOELECTRIC SOLAR GENERATOR].
Cooperation Mediterraneenne pour l'Energie Solaire, Bulletin, 8:101-103, May 1965. In French.

Description of a thermoelectric solar converter for directly converting solar to electrical energy, based on the Seebeck effect, which uses two semiconductors with a temperature gradient between their junctions. The conversion efficiency is defined as the ratio between the electric power generated P and the heat power Q supplied to the thermocouple. The power Q may be expressed as a function of three phenomena - the Peltier effect, the Joule effect, and thermal conduction. It is shown that Carnot's efficiency is the maximum which limits power output. The thermocouple elements are Te-Pb and Te-Ge combinations. A parabolic mirror focuses the solar rays to produce a temperature of 500°C in a black, spherical, hollow body, open at the point of focus. Two n-type junctions fit snugly against the upper part of this body with light pressure provided by springs to ensure good contact, while between these two there is a similarly mounded p-type junction. One square meter of mirror area produces 12 watts.

635. Tingwaldt, C. and Seemann, F. W.
PHOTOELECTRIC, THERMOELECTRIC AND THERMIONIC CONVERSION OF SOLAR ENERGY INTO ELECTRICAL ENERGY.
Brennstoff-Warme-Kraft, 14:329-333, Jly. 1962. In German.

Studies are beginning on pulsed operation of fuel cells and space-biocell experiments.

627. Szego, G. C.
SPACE POWER SYSTEMS STATE OF THE ART.
Journal of Spacecraft and Rockets, 2:641-659, Sept.-Oct. 1965.

This paper surveys the state of the art of the space power systems and components and associated technologies in the United States. Included are: solar power system, chemically fueled power systems, systems for nuclear auxiliary power, dynamic machinery for space power, radioisotope space power, thermoelectric systems, thermionic energy conversion, magnetohydrodynamic power generation, and batteries and fuel cells.

628. Tabor, H. and Zeimer, H.
LOW-COST FOCUSING COLLECTOR FOR SPACE POWER UNITS.
Solar Energy, 6:55-59, figs., Apr.-June 1962.

A focusing collector for producing heat from solar radiation for power use consists of an inflated cyclinder of plastic film 12 meters long and 1.5 meters in diameter. The cylinder is made in two segments, the portion exposed to the sun being clear plastic that acts as a mirror. The circular section is shown to be superior to a parabola for overall focusing and, in addition, is both easier and less expensive to form. The collector, including end rings, weighs only 1.2 kg per square meter of solar aperture. Being deflatable, it is portable. Cost is estimated as $20 per square meter of solar reception. Collection efficiency is about 40 percent.

629. Tallat, M. E.
DIRECT ENERGY CONVERSION.
Industrial Research, 6:67-75, May 1964.

The four most important means of direct energy conversion - magneto-plasmadynamic, thermionic, and thermoelectric generators, and the fuel cell - are reviewed. Power range, operating temperature, life-time, efficiency, size, and stage of existence - experimental or working model - are discussed for each.

630. Teller, E.
NUCLEAR POWER POTENTIAL FOR SPACE.
In Bureau of Naval Weapons. Missiles and Rockets Symposium, April 1961. Proceedings, p. 15-17, Concord, Calif., U. S. Naval Ammunition Depot, Apr. 1961.

General talk on use of unclear power with an indication of possibilities for use in space.

Gives a review of the papers of the United Nations Conference on New Sources of Energy, August 1961 in Rome. Various types of solar generator are illustrated and described including solar batteries.

636. Touryan, K. J.
A HYPERSONIC PLASMA POWER GENERATOR.
American Institute of Aeronautics and Astronautics Journal, 3:652-659, Apr. 1965.

A power generation technique is described in which the nose cone of a reentry vehicle serves as a thermionic emitter of electrons; the electrons are then conducted through the shock ionized air stream, increased in kinetic energy by collisions, collected over the relatively cool vehicle afterbody, which is electrically insulated from the nose cone and which serves as an anode or collector; a load connected between the cathode and anode within the vehicle completes the circuit.

637. Treco, R. M.
HOW SPACE-AGE ENERGY SOURCES SPARK RISE OF NEW MATERIALS.
Iron Age, 187:87-89, Mar. 2, 1961.

Problem of power plants for space vehicles discussed; nuclear energy appears to be the answer when power levels higher than 10 kw for 10-100 hr are needed. Three cooling methods for nose cone are now under study; other critical areas in rockets and missiles are noted and materials considered. Problem of radiation and high-temperatures when using nuclear power stations and efficiencies of energy conversion devices are discussed.

638. TUBES CONVERT HEAT: THERMIONIC CONVERTER.
Electronics (Bus. ed) 30:29, Dec. 10, 1957.

This is essentially a news item about the GE thermionic converter which is reported to have an 8% efficiency compared with thermocouples with less than 1% efficiency. Metals in the GE converter are separated by ionized gas at low pressure. One electrode is held at 2500° F. This reduces the space charge around the emitter and increases the efficiency of the converter. The intense heat of guided missiles may one day be used in converters for powering guidance and telemetering equipment.

639. Turrin, A. D. and Blau, A.
SOLAR DYNAMIC POWER SYSTEMS FROM 3 to 100 KW.
New York, American Institute of Aeronautics and Astronautics, 1964, 16 p. (Paper 64-724.)

Evaluation of the power system weight, size, and volume characteristics in the useful power range of a mercury Rankine solar system. The missions studied are the near-Earth, all-Sun, and maximum-shade

orbits. The conventional approach is followed for cycle parameter selection, system component selections, and weight and size evaluations. In general, the final configurations and characteristics of a given power system are determined by relative tradeoffs to optimize the power supply system for the specific mission objectives. The general approach taken in the high-power studies is that of preference to system weight relative to volume. Consideration is given to minimum packaging volume by use of deployable or telescoping structures.

640. Ulmer, R. C. and Sensenbaugh, J. D.
DIRECT CONVERSION OF ENERGY TO ELECTRICITY.
Combustion, 32:30-38, illus., Aug. 1960.

Unconventional methods of power generation are classified; the field of application of each is indicated, as well as the current state of development. Mentioned are piezoelectric generation; electric generators; solar energy converters; photochemical conversion; nuclear energy converters; SNAP-III; fuel cells; thermionic converters; and thermoelectric generators.

641. Ulvönäs, S.
ELECTRIC CELLS AND BATTERIES.
Teknisk Tidskrift, 90:713-718, Aug. 5, 1960. In Swedish.

A review of new cell types with a view to their application in missiles and satellites. A table is given showing the main electrical characteristics as well as weight, volume and density for nine types of cell grouped under dry cells, mercury cells, air-depolarized cells, Ni-Cd accumulators, Ag-Zn accumulators and lead accumulators.

642. Unger, H. E.
NUKLEARE ENERGIEVERSORGUNGSANLAGEN OHNE KONVEKTIVEN WAERMETRANSPORT FUER RAUMFLUGGERAETE [NUCLEAR SPACE POWER UNITS WITHOUT CONVECTIVE HEAT TRANSFER].
Atomkern Energie, 10:375-382, Sept.-Oct. 1965. In German.

Advantages and disadvantages of nuclear thermionic space power units without convective cooling are discussed. Systems and projects, which have been studied so far by various institutions are described and compared. Their investment of fissile material amounts to values of 50 to 1300 kg at a power range of 0.5 to 1000 kW electric. The specific power varies between 1 and 200 W/kg. The latter value seems to be achievable if those systems are intensely developed.

643. van Dohren, H. H.
BRENNSTOFFZELLEN - CHEMOELEKTRISCHE ENERGIEUMWANDLER DER ZUKUNFT [FUEL CELLS AS FUTURE CHEMICAL-ELECTRIC ENERGY CONVERTERS].
Internationale Elektronische Rundschau, 19:63-67, Feb. 1965. In German.

Survey of the present technological state of direct chemical-to-electric energy conversion. The structural design and principles of operation of fuel cells are examined together with some practical applications. The principal types of fuel cells are reviewed.

644. Van Heyst, H. P. and Cunningham, T. M.
Si-Ge THERMOELECTRIC POWER MODULES.
In Power Sources Conference Proceedings, 18th, May 19-21, 1964, p. 130-134. Red Bank, N. J., PSC Publications Committee, 1964.

Thermoelectric power systems using thermal energy from the combustion of fossil fuels such as gasoline, kerosene, diesel fuel, and propane, are currently being considered for many special military applications. Systems of this type, which can be developed to provide power outputs ranging from a few watts to kilowatts, have the potential advantages of relatively silent operation, elemination of moving parts, and the ability to produce power reliably for long periods without maintenance or attended operation. Because the attainment of the technology required for these applications seems assured, the broader application of fossil-fueled thermoelectric generators depends to a large extent on reducing costs with no sacrifice in reliability and performance.

645. Varsharvskii, G. A. and Rezgol, I. A.
ANALIZ KHARAKTERISTIK ODNOKONTURNOI KOSMICHESKOI ENERGOUSTANOVKI S TERMOELEKTRICHESKIM PREOBRAZOVATELEM [ANALYSIS OF THE CHARACTERISTICS OF A SINGLE-CIRCUIT SPACE POWER INSTALLATION WITH A THERMOELECTRIC CONVERTER].
Akademiia Nauk SSSR, Izvestiia, Energetika i Transport, p. 120-126, Jan.-Feb. 1967. In Russian.

Results of a design study for a thermoelectric generator of a single-circuit space power installation. The temperature distribution, capacity, and heat transfer of the generator are determined by reducing a set of finite-difference equations to a single differential equation. A simple case of generator optimization is analyzed.

646. Venchiarutti, R.
APPLICAZIONI SPAZIALI DELL'-ENERGIA NUCLEARE NEI SISTEMI ELETTROGENERATORI. I. [SPACE APPLICATIONS OF NUCLEAR ENERGY IN ELECTRIC GENERATING SYSTEMS. I.].
Missili, 5:213-227, Aug. 1963. In Italian.

Discussion of the problem in the field of space flights posed by the necessity of equipping space vehicles with a safe and adequate power source for their auxiliary systems, communications, and stabilization, and for electric propulsion systems (electrothermal, MHD, ionic). Considered and discussed are the principal concepts of radioisotope and jet sources of a nuclear type for space uses, for coupling to one of the following conversion systems: (1) turboelectric, (2) thermoelectric, and (3) thermionic. Briefly mentioned are some experimental accomplishments and future possibilities.

647. Vignet, P.
USE OF NUCLEAR ENERGY FOR THE PRODUCTION OF ELECTRICITY BY ELECTRO-CHEMICAL CONVERSION.
Energie Nucleaire, 6:3-17, Jan.-Feb. 1964. In French.

Chemical and radiation sources of energy for direct conversion systems are compared, together with performance.

648. Villers, P.
APPLICATION OF SOLAR-SAIL ATTITUDE STABILIZERS TO THERMIONIC POWER GENERATION.
Journal of Spacecraft & Rockets, 2:976-978, Nov.-Dec. 1965.

A solar-sail attitude stabilizer is combined with the solar collector of a thermionic power generator. The solar sail performs two distinct attitude stabilizing functions: (1) provides moderate accuracy pointing of the entire payload in the face of moderately large distabilization torques and (2) uses a solar thermionic concentrator as a self-stabilizer to point a solar thermionic generator assembly toward the sun to a higher accuracy than the main payload.

649. Vohl, P., Addiss, R. R., Perkins, D. M., Ellis, S. G., Hui, W. and Noel, G.
GaAs THIN-FILM SOLAR CELLS.
IEEE Transactions on Electron Devices, ED-14:26-30, Jan. 1967.

Thin-film solar cells utilizing polycristalline gallium-arsenide films have been made and investigated to determine their suitability for future solar-power systems. The gallium-arsenide films are vapor deposited onto substrates of molybdenum or aluminum foil. Of the various junctions investigated, the most successful has been one consisting of a surface barrier employing an evaporated film of platinum or semiconducting copper selenide. The efficiencies of platinum gallium-arsenide barriers on molybdenum substrates have been 3% for 4 cm^2 area, 4.5% for 2 cm^2 area and 5% for 0.2 cm^2 area. For copper selenide gallium-arsenide barriers on molybdenum an efficiency of 4.6% for 0.73 cm2 area has been measured; using aluminum substrates this figure is 4.3% for the same area with a power-to-weight ratio in excess of 135 watts/lb. With an etching treatment, cells made with copper selenide barriers have shown no degradation on the shelf or under load at room ambient.

650. Voltz, S. E. and Kerr, D. L.
FUEL CELLS FOR SPACE POWER SYSTEMS.
Society of Automotive Engineers Transactions, 71:247-252, 1963.

Two hydrogen-oxygen fuel cells are described and their performance feasibilities as components in space power systems are discussed.

651. Voltz, S. E. and Read, M. D.
REGENERATIVE HYDROGEN-OXYGEN FUEL CELL.
Institute of Radio Engineers Transactions, ME-6:63-67, Jan. 1962.

The regenerative hydrogen-oxygen ion-exchange membrane fuel cell is especially suitable for use in space power systems. Cells have been operated initially at current densities of 38 and 100 a per square foot at 0.8 and 0.6 v, respectively. Multicell units have been built and tested. Experimental fuel-cell batteries have been tested under zero-gravity conditions in aircraft and have been flown in missile flights. The results have shown that this fuel cell operates satisfactorily in the environment of outer space.

652. Voltz, S. E. and Kerr, D. L.
WHAT PLACE IN SPACE FOR FUEL CELLS?
Society of Automotive Engineers Journal, 70:48-49, figs., Mar. 1962.

Estimates performance and most likely fields of use for both primary and secondary fuel cells in space power applications.

653. von Doenhoff, A. E. and Premo, D. A.
A BRIEF SURVEY OF DIRECT ENERGY CONVERSION DEVICES FOR POSSIBLE SPACE-VEHICLE APPLICATION.
Institute of Radio Engineers Transaction, MIL-3:46-51, Apr. 1959.

A brief review is given of various types of devices for converting heat or radiant energy directly into readily available electrical form. These devices include the thermoelectric generator, the photovoltaic cell, the thermionic converter, and the photoemissive converter. The discussion is from the point of view of possible space-vehicle application. An attempt is made to indicate in a general way the present state of development, the advantages and difficulties associated with each device, and to suggest general lines of future research.

654. von Doenhoff, A. E. and Hallissy, J. M., Jr.
SYSTEMS USING SOLAR ENERGY FOR AUXILIARY SPACE VEHICLE POWER.
In Seminar on Advanced Energy Sources, 1958. Proceedings, p. 233-241, Fort Monmouth, N. J., 1959?

Solar energy conversion devices are discussed.

655. Vondracek, C. H.
INORGANIC INSULATION FOR ELECTRICAL EQUIPMENT IN SPACE ENVIRONMENTS.
Seattle, Society of Aerospace Material and Process Engineers, 1963, 14 p.

Discussion of the necessity for inorganic electrical insulation in solving many of the insulation problems of space electrical power systems now under development. It is stated that, in certain applications, this form of insulation will offer superior properties in thermal stability, radiation resistance, thermal conductivity and low volatility.

656. von Szabo, E.
THERMOELEKTRISCHE GENERATOREN FUR HOHE LEISTUNGEN [THERMOELECTRIC GENERATORS FOR HIGH PERFORMANCE].
In Energy Supply in Space; Deutsche Gesellschaft fur Raketentechnik und Raumfahrt, Symposium, Stuttgart, West Germany, December 8, 1965, Lectures p. 175-187. Munich, Deutsche Gesellschaft fur Raketentechnik und Raumfahrt, 1966 (Fortschritte in der Raumfahrtforschung, vl. 2). In German.

Review of the advancements made in the application of thermoelectric generators for space-flight purposes. The component parts in the design of such generators are outlined, and the parameters of the thermoelectric generator are discussed. The electrical data and the technology of the structural parts are reviewed. The reactor-type thermoelectric energy supply system and the nuclide-thermo-electric energy supply system are described.

657. Voorhees, B. G.
THERMIONIC CONVERSION FOR SPACE AUXILIARY POWER GENERATION.
Chemical Engineering Progress, Symposium Series, 75:110-116, 1967.

Study of thermionic conversion, which possesses significant potentials for the attainment of highly reliable, long-lived space auxiliary power systems. A summary is presented of the state of the art of the theory of the thermionic converter and of power output and efficiency performance levels which have been measured with operating converters. The application of thermionic conversion for space power generation is surveyed. For smaller space power systems, the use of solar heating and radioisotope heating with thermionic converters is seen to be particularly well suited. For large systems the use of nuclear reactor heating is examined. Four nuclear thermionic concepts are compared, and the two most promising are described in more detail. The current status of key research and development area is summarized.

658. Voshall, R. E. and Emmerich, W. S.
MHD POWER GENERATION WITH PHOTOIONIZATION.
IEEE Transactions on Aerospace, AS-2:807-815, Apr. 1964.

The recent development of an efficient source of focused, continuous, visible and ultraviolet light has aroused interest in photoionization as a means of enhancing the conductivity in MHD channels. This process has been examined for applications in space MHD generators employing Brayton and Rankine cycles. Details for an example of an MHD space power generating system using this type of ionization are presented.

659. Watt, G. W. and Skene, E. M.
OPERATION OF WEAPON SYSTEM LOADS FROM RURAL POWER SYSTEMS.
IEEE Transactions on Aerospace and Electronic Systems, AES-2, Suppl.: 762-770, Jly. 1966.

Consideration of problems of operating unattended weapons systems on rural power systems. Criteria for switching to alternate power sources are developed, and appropriate specifications are proposed for the power sensing devices. Emphasis is placed on special fault patterns frequently not detected by simple sensing techniques. Improperly designed or inadequate sensing equipment or circuits will permit faulty commercial power to remain connected to the load, with resultant catastrophic damage. Sophisticated power sensing equipment is required to initiate a transfer from normal to standby and emergency power systems. Factors involved are low voltage, unbalanced voltages, reversed phase rotation, or loss of neutral.

660. Webb, M. J. and Whitmer, D. A.
THE APPLICATION OF PACKAGED LIQUID ROCKET POWERPLANTS TO METEOROLOGICAL ROCKETS.
In American Institute of Aeronautics and Astronautics, Sounding Rocket Vehicle Technology Specialist Conference, Williamsburg, Va., February 27-March 1, 1967, Technical Papers, p. 313-319. New York, American Institute of Aeronautics and Astronautics, Inc., 1967.

Description of the functional behavior and characteristics of packaged liquid power plants and indication of how they are particularly applicable to the meteorological rocket. The design and performance of a packaged liquid power plant are discussed for a boosted-dart type of meteorological rocket for a nominal service altitude of 60 km. It is indicated that alternate service altitudes may be simply obtained by minor changes to the basic 60-km design.

661. WESTINGHOUSE STAFF SEEKS NEW ELECTRIC POWER SOURCES.
Research Development, 11:28-32, illus., May 1960.

Four approaches under particular investigation are described - fuel cells, thermoelectricity, thermionic conversion and magnetohydrodynamics.

662. Wheeler, N. D.
SURVEY OF ELECTROCHEMICAL BATTERIES.
Electro-Technology, 71:68-73, June 1963.

This article presents a survey of data on presently available electrochemical cells. It is intended to aid the reader in selecting an optimum energy source for any device that requires battery power.

663. White, E. A., Jr.
MAGNETOHYDRODYNAMIC GENERATOR.
U. S. Patent 3, 156, 433, Jan. 10, 1962, (to The United States of America as represented by the Secretary of the Navy).

The combination comprising; a space vehicle having a passageway therethrough extending from an inlet port to an outlet port, a load device in said vehicle to be actuated by electrical energy, and an MHD generator positioned within said vehicle, operatively associated with said passageway and connected to said load device whereby the passage of said vehicle through space causes ionized fluid to pass through said generator thereby generating electrical energy for actuating said load device, said inlet port of said passageway being located in a relatively lower pressure surface of said vehicle and said outlet port of said passageway being located in a relatively lower pressure surface of said vehicle, whereby the passage of said vehicle through space produces a ram-jet flow of said ionized fluid from said inlet port to said outlet port through said generator, said vehicle being subjected to a high velocity spin about a central axis, and said outlet port being located radially outward of said inlet port, whereby said ionized fluid is further accelerated through said generator by centrifugal pumping action. (U.S. Patent Off.Off.Gas., 808:538, Nov. 10, 1964.)

664. Whyte, E.
SECONDARY POWER SYSTEMS FOR SPACE VEHICLES.
Canadian Aeronautics Journal, 6:331-336, Oct. 1960.

Compares available systems, e. g., mechanical, chemical, solar energy, thermoelectric, thermionic and nuclear and relates them to the nature and duration of operation required.

665. Wilburn, N. T.
DEVELOPMENT AND RELIABILITY INVESTIGATIONS OF ZINC-SILVER OXIDE MISSILE BATTERIES.
In Battery Research and Development Conference, 11th, 1957, p. 58-61, illus., Fort Monmouth, N. J., U. S. Army Signal Engineering Laboratories, 1957.

The development of automatically activated zinc-silver oxide batteries is reviewed, and the test to destruction concept is briefly discussed as it relates to incorporating design reliability into a specific missile battery.

666. Wilburn, N. T.
A RELIABILITY PROGRAM FOR MISSILE BATTERIES.
In Power Sources Conference Proceedings, 18th, May 19-21, 1964, p. 71-75. Red Bank, N. J., PSC Publications Committee, 1964.

This paper deals with a new procedure for establishing the reliability of one-shot items under simulated operational environments where extremely high reliability is required.

667. Williams, K. R., Pearson, J. W. and Gressler, W. J.
LOW TEMPERATURE FUEL BATTERIES.
In Collins, D. H. ed., Batteries 2; International Symposium, 4th, Brighton, England, September 29-October 1, 1964, Proceedings, p. 337-347. Oxford, Pergamon Press, Ltd., 1965.

Description of a battery consisting of hydrogen/oxygen alkaline fuel cells and capable of operating at low temperatures and pressures. Design considerations for a low-temperature, two-gas fuel cell are outlined. The type and shape of electrodes chosen for the hydrogen/oxygen cell are described, and the layout and operating conditions selected for the cell are discussed. A battery using 21 of these cells is described which can provide 250 watts at 12 v when operated between 25 and 30°C and 2-1/2 lb/in.^{2} gas pressure.

668. Williams, K. R.
THE STATUS, PROBABLE DEVELOPMENT AND APPLICATIONS OF FUEL CELLS.
In Williams, K. R. ed., An Introduction to Fuel Cells, p. 310-318, New York, American Elsevier Publishing Co., Inc., 1966.

Recapitulation of some of the points that have emerged from the detailed consideration of different fuel cells. It is noted that there is no doubt that fuel costs will play a dominant part in determining the acceptance of fuel cells. Hydrocarbon fuels used at an efficiency of 50% would certainly be a very attractive proposition in some applications. In applications where load factors are low and instant starting is important, it appears at present that methanol fuel cells are likely to be needed. The user, it is noted, would have to accept the more expensive fuel as the price for added convenience; power units for electric delivery vehicles and the like would fall into this category.

669. Williams, T. L. and Etzweiler, G. A.
DYNAMIC CONTROL OF HIGH-PERFORMANCE TWO-PHASE SERVOMETERS.
In 1967 Joint Automatic Control Conference, University of Pennsylvania, Philadelphia, Pa., June 28-30, 1967, Preprints of Papers, p. 418-426, New York, Lewis Winner, 1967.

A method for eliminating the electrical transients in high-performance sleeve induction motors is shown whereby response times of 1 msec can be achieved. Improved dynamic performance and a five-fold reduction in the standby power normally required are gained by using phase modulated, variable amplitude inputs to both the control and reference windings. The reduction in the input power and response time is obtained at the expense of additional complexity in the drive system which requires an SCR inverter and two multipliers. The proposed system will probably be most useful for critical applications such as in missile guidance control systems.

670. Willmore, A. P.
ROCKET AND SATELLITE SYSTEMS.
In Ortner, J. and Maseland, H. eds., Introduction to Solar Terrestrial Relations; Proceedings of the Summer School in Space Physics, Alpbach, Austria, July 15-August 10, 1963, p. 317-323, Dordrecht, Netherlands, D. Reidel Publishing Co., 1965.

Discussion of considerations for the design of the supporting systems in scientific rockets and satellites. Design limitations as they currently exist are reviewed, and possible future developments to overcome them are noted in connection with the design of the power generation and distribution system and the data storage and transmission system for a typical small satellite. In addition, the need to take ground data-reduction requirements into account when designing a satellite or rocket experiment is discussed.

671. Wilson, G. W.
SMALL NON-CONVENTIONAL ELECTRICAL POWER SOURCES.
British Interplanetary Society Journal, 19:81-86, May-June 1963.

The present status of each of three methods of conversion of heat or light into electrical power without the use of rotating machinery is surveyed: thermoelectricity, thermionic conversion, and photovoltaic converters. A comparison of practical devices indicates that for some time each method will find specialised applications.

672. Wilson, V. C. and Lawrence, J.
OPERATING CHARACTERISTICS OF TWO THERMIONIC CONVERTERS HAVING RHENIUM-NICKEL AND TUNGSTEN-NICKEL ELECTRODES.
Advanced Energy Conversion, 4:195-221, Dec. 1964.

The effect of various electrode materials on the output characteristics of high pressure cesium thermionic converters was studied. Two parallel plane thermionic converters were constructed and tested, one with a rhenium emitter and a nickel collector surrounded by a nickel guard ring and the other with a tungsten emitter and nickel collector and guard. The Re-Ni converter had higher output voltages at equal emitter temperature and current densities. Both converters had high output densities.

673. Wilson, V. C. and Hamilton, R. C.
THERMIONIC CONVERTERS FOR SPACE POWER.
Astronautics and Aerospace Engineering, 1:62-67, May 1963.

No longer merely "interesting" as back-up devices, converters today warrant serious consideration for space vehicles.

674. Windle, W. F.
MICROWATT RADIOISOTOPE ENERGY CONVERTERS.
IEEE Transactions on Aerospace, AS-2:646-651, Apr. 1964.

Brief survey of proposed radioisotope conversion systems, followed by a detailed description of two systems particularly suited for microwatt power sources. First, a 10^{-9} ampere Kr^{85} β current cell capable of tens of kilovolts, now in limited production, is presented, followed by a discussion of other possible future β current cells. Second, some theoretical considerations of a Pm^{147} silicon electronvoltaic converter with an output in the range of $100\mu A/cm^2$ at a few tenths of a volt are discussed. Some applications adapted to each system are also presented.

675. Wing, L. D. and Cameron, K. E.
SOLAR COLLECTORS FOR USE IN THERMIONIC POWER SUPPLY SYSTEMS IN SPACE.
ARS Journal 31:327-334, Mar. 1961.

The optical aspects of a solar-thermionic power system are described. Various design considerations are presented along with an analytical approach. A modular concept is proposed, and definitions of the problem areas, such as collector fabrication, are followed by an engineering approach to the system design in which a method is presented to decrease the stringent solar alignment tolerance.

676. Winkle, J. V. and Carson, W. N.
OPTIMIZATION CALCULATIONS FOR FUEL CELL SYSTEMS.
Electrochemical Technology, 1:18-22, Jan.-Feb. 1963.

Many fuel cell applications require the minimization of the weight, volume or cost of the fuel cell system. This paper provides the method for combining the characteristics of the application, the fuel supply and the fuel cell itself to determine the design point for the desired minimum. The procedure consists of formulating the total system size in terms of the cell operating voltage and determining the value of the cell voltage which makes the total a minimum. The procedure is entirely general for fuel cell systems regardless of their specific characteristics or of the fuel and oxidant combination used. It provides the theoretical derivation for the figure of merit for the total fuel cell system in a particular application.

677. Winkler, S. H.
OPTIMUM DESIGN OF A SPACE VEHICLE STORAGE SYSTEM.
In Power Sources Conference. Proceedings, 14th, p. 90-93, Red Bank, N. J., PSC Publications Committee, 1960.

The discussion is concerned with the design of storage systems the requirement for which is that they may be charged in the daytime and deliver energy at night.

678. Winnard, W. H., Jr.
ROCKETRY AND RELATED FIELDS.
Jet Propulsion, 26, (Pt. 2) illus., Oct. 1956.

Auxiliary power units are briefly described.

679. Wise, J. F.
DENDRITIC SILICON SOLAR CELLS AND UTILIZATION EXPERIENCE.
IEEE Transactions on Aerospace and Electronic Systems, AES-2, Suppl.: 85-92, Jly. 1966.

Discussion of the fabrication and performance of denditric silicon solar cells. Array and system experience gained with such cells are summarized.

680. Wise, J. F.
SOLID-STATE CONVERSION CONCEPTS FOR SPACE NEEDS.
Electrical Engineering, 81:864-868, Nov. 1962.

Various solid-state energy conversion concepts under development are discussed from the standpoint of present capabilities to satisfy aerospace vehicle electric power needs. Energy sources considered are solar, nuclear, chemical, and acoustic, with emphasis on solar and nuclear.

681. Wolf, M. and Ralph, E. L.
EFFECT OF THICKNESS ON SHORT-CIRCUIT CURRENT OF SILICON SOLAR CELLS.
IEEE Transactions on Electron Devices, ED-12:470-474, Aug. 1965.

Discussion of the theoretical and experimental results of an investigation of the change in a short-circuit current in high performance N/P silicon solar cells as a function of the cell thickness. The dependence of this effect on the spectral distribution of irradiating light from a tungsten filament at 2800°K, sunlight on Table Mountain, Calif., and a sunlight simulator and on the minority carrier lifetime and mobility in the base section of a solar cell is investigated. It is noted that even a small reduction of the cell thickness decreases markedly the short-circuit current (due to lower collection efficiency at long wavelengths) in modern N/P silicon solar cells. Decreased radiation sensitivity of the thinner solar cells is established and is assessed as their positive property useful in some cases.

682. Wolf, M.
THE PRESENT STATE-OF-THE-ART OF PHOTOVOLTAIC SOLAR ENERGY CONVERSION.
Solar Energy, 5:83-94, figs., Jly.-Sept. 1961.

The present state-of-the-art in photovoltaic solar energy conversion, in particular, as applied for space vehicle power supplies is summarized. Past and future development goals are lower weight-to-power and cost-to-power ratios, higher reliability, and increased useful lifetimes. Recent improvements introduced in the present standard device, namely, the silicon solar cell, are discussed. They include application of metallic grids for the reduction of series resistance and change of the p-layer thickness for improved spectral

response. Further, attempts to develop methods for preparing large area and thin film silicon solar devices are reviewed and finally a survey is given of the progress made in the application of other semiconductor materials to solar photovoltaic energy conversion. Here the work on cadmium sulphide solar cells stands out due to the achievement of solar conversion efficiencies of up to 4-1/2% on thin film cells.

683. Wolff, M. F.
WANTED: RADIATION-RESISTANT SOLAR CELLS.
Electronics, 35:28-29, Sept. 21, 1962.

Because of increased radiation in space, solar cells may be redesigned. Approaches considered include: n-on-p cell, made by diffusing phosphorus into the surface of a p-type silicon crystal; the graded-base solar cell, where a gradient in the base impurity concentration is introduced by diffusion; or to use gallium arsenide instead of silicon.

684. Wray, W. J., Jr., Ottaviano, A. V., Freestone, H. T. and Brown, J. S.
A 30X5 MICROELECTRONIC COMMUTATOR.
In Aerospace Electrical Society, Annual Aerospace Electrical/Electronics Conference, 21st, Los Angeles, Calif., October 9-11, 1963, p. 71-87, North Hollywood, Western Periodicals Co., 1963.

Description of a commutator designed, constructed, and tested for missile and space vehicle environments. The following are described: general commutator functions; system implementation, including transmission gates, distributor, and power supply; construction, including multilayer printed board assembly and welded cordwood assembly; environmental tests; and specifications.

685. Wuerflein, D. E.
MINIATURIZED POWER CONVERSION TECHNIQUES.
In Wescon/65; Proceedings of the Western Electronic Show and Convention, San Francisco, Calif., August 24-27, 1965, Technical Papers. Part 3 - Power Electronic, p. 1-6, North Hollywood, Calif., Western Periodicals, Co., 1965.

Outline of a general approach to design of power converters and regulators up to 100 kc, together with the problems involved and some solutions to them. Series dissipative and series switching type regulators and inverters are discussed, together with radio frequency interference and packaging. An example of a miniaturized power supply is described, and design trends are studied. It is concluded that future developments in power transistors will probably minimize the "storage time" effect, which will render circuit design less difficult.

686. Wynveen, R. A.
FUEL CELL TECHNOLOGY - A SURVEY OF ADVANCES AND PROBLEMS.

In Friend, J. A. and Gutmann, F. eds., Australian Conference on Electrochemistry, 1st, Sydney and Hobart, Australia, February 13-20, 1963, Proceedings, p. 611-633, Oxford, Pergamon Press, Ltd., 1965.

Survey of recent progress in fuel cell technology, with the object of evaluating the state of development of cells for various proposed applications. The cells considered are classified according to the range of fuel costs into (1) cells using zinc-oxygen, sodium-oxygen, hydrogen-oxygen, and hydrogen-air (expensive fuels), (2) cells using methanol-air and methanol-oxygen (medium-cost fuels), and (3) hydrocarbon-air fuel cells (low-cost fuels). The survey includes: hydrogen-oxygen fuel cells, cells employing carbon electrodes, high-temperature/high-pressure cells, the Justi cell, solid electrolyte systems, organic and inorganic membranes, and the vehicle-held electrolyte system. Energy storage through regenerative hydrogen-oxygen fuel cells is examined. The hydrocarbon-air fuel cells include: the low-temperature hydrocarbon-air cells (100°C), intermediate-temperature cells (100-to 200°C), high-temperature cells (400 to 1100°C), molten alkali carbonate cells, and solid-electrolyte cells. Group (3) includes the alcohol fuel cells and the ammonia fuel cell. Some progress achieved with cells using special fuels is considered, such as the sodium-amalgam/oxygen fuel cell and the biochemical fuel cell. Development trends in fuel-cell technology are noted, and areas requiring further research are indicated.

687. Wynveen, R. A.
PRELIMINARY APPRAISAL OF THE AMMONIA FUEL CELL SYSTEM.
In Fuel Cells, vl. II, p. 153-167, New York, Reinhold Publishing Corp., 1963.

Investigation of ammonia as a fuel and of the complete ammonia-oxygen system. Ammonia and its characteristics are discussed, and some of the typical data obtained with several preliminary ammonia-oxygen fuel cells is presented.

688. Wynveen, R. A. and Deibel, D. L.
UTILIZING THE Li-Cl_2 POWER PLANT FOR CRITICAL WEAPONS APPLICATIONS.
In Intersociety Energy Conversion Engineering Conference, Los Angeles, Calif., September 26-28, 1966, Technical Papers, p. 259-265, New York, American Institute of Aeronautics and Astronautics, 1966.

Summary of the theory and technology of the Li-Cl_2 powerplant and examination of its application to various typical weapons systems. The lithium-chlorine powerplant is described and typical critical weapons applications are reviewed. Five weapons applications are considered, including missile control and guidance, penetration aids, torpedo main propulsion, limited war-forward zone, and man-pack equipment. A comparison of powerplant weights is tabulated. An outline of the development work remaining is presented.

689. Wysocki, J. J., Rappaport, P., Davison, E., Hand, R. and Loferski, J. J.
LITHIUM-DOPED, RADIATION-RESISTANT SILICON SOLAR CELLS.
Applied Physics Letters, 9:44-46, Jly. 1, 1966.

Results indicating that the use of lithium in silicon devices leads to a significant improvement in their ability to withstand radiation. It is found that when Li is the dominant impurity in floating-zone, n-type Si, a new center, formed by electron irradiation, preserves the minority-carrier lifetime, thus yielding devices which are more radiation-resistant.

690. Yaffee, M.
UNIT CONVERTS WASTE ROCKET HEAT TO POWER.
Aviation Week, 71:92-93, 97, 99-100, illus., Nov. 23, 1959.

Relates characteristics, possible applications and remaining problems of a thermionic auxiliary power unit developed by RCA and Thiokol Chemical Corporation which converts waste heat from a rocket exhaust directly into electricity.

691. Yardney, M. N.
STORAGE BATTERY PICTURE HAS SILVER LINING IN MISSILES AND ROCKETS.
Jet Propulsion, 25:42-S-43-S, Sept. 1955.

Description of the Yardney Silvercellstorage batteries and their applications.

692. Yeager, P. B.
NEW SOURCES OF ELECTRIC POWER ARE COMING.
Nations Business, 48:72, 88, Dec. 1960.

Briefly mentions the fuel cell, its types, uses, and advantages; the plasma generator and how it operates; and photoelectric power and solar energy.

693. Young, G. J. ed.
FUEL CELLS. VOLUME II.
New York, Reinhold Publishing Corp., 1963, 225 p.

Collection of papers concerning the development and advancement of fuel-cell technology. Data are included on the progress toward the long-sought objective - the hydrocarbon-air fuel cells. Other aspects covered include high-temperature methane fuel cells, solid-oxide-electrolyte cells, radiation-induced activation of oxygen electrodes, and polarization at diffusion electrodes.

694. Zachmann, H. C.
ELECTRIC POWER FOR SPACE VEHICLES.
Aerospace Engineering, 21:68-69, 78, 82-86, May 1962.

Various types of generators are discussed, including silicon photo cells, thermionic generators, thermoelectric methods and fuel cells. Energy storage is also briefly mentioned.

695. Zahn, P.
DEVELOPMENT OF A RADIOISOTOPE THERMOELECTRIC POWER GENERATOR.
In Industrial Applications for Isotopic Power Generators, p. 435-450. Paris, European Nuclear Energy Agency, 1967.

The status of the development work of a thermoelectric conversion system is outlined and a special compact GeSi-converter element is presented. With these elements an actual model of a space power generator with an electrical output of 125 W was constructed. The model was subjected to vacuum tests with an electrical simulated heat source. In addition, an outlook is given on the future performance characteristics of radioisotope thermoelectric power generators.

696. Zarem, A. M.
POWER SYSTEMS.
Astronautics, 5:43, 102, 104-106, illus., Nov. 1960.

Chemical, solar and nuclear systems in a number of variations are discussed. Fuel cells progress is described and cryogenic and electrochemical storage.

697. Zener, C.
THERMOELECTRICITY. ITS IMPACT UPON SCIENCE AND TECHNOLOGY.
Industrial Science and Engineering, 5:26-30, figs., Oct. 1958.

A general article giving background information, reasons for resurgence of interest in thermoelectricity and possible future applications.

698. Ziegler, H. K.
ENERGY SOURCES FOR "SPACE-AGE" ACTIVITIES.
In Battery Research Conference. Proceedings, 12th, p. 100-104, Fort Monmouth, N. J., U. S. Army Signal Research & Development Laboratory, Power Sources Division, 1958.

A review of the advantages and disadvantages of energy sources and power systems which promise or have already proven capabilities for space application.

699. Zimmerman, R. L.
SPACE VEHICLE POWER SYSTEMS.
ARS Journal, 29:553-564, Aug. 1959.

Review of systems utilized for generation of secondary and/or propulsion power: chemically-fueled power, open and closed cycle; solar power, closed cycle; nuclear power, closed cycle; thermionic and thermoelectric power; solar photovoltaic and solar recycling

fuel cell power. Discusses typical systems, general physical construction and limitations, comparisons of systems and selection for various missions.

700. Zoutendyk, J. A.
A METHOD FOR PREDICTING THE EFFICIENCY OF SOLAR CELL POWER SYSTEMS OUTSIDE THE EARTH'S ATMOSPHERE.
Proceedings of the Solar Working Group Conf., February 27-28, 1962, p. 1-35, Washington, Interagency Advanced Power Group, 1962.

A method for predicting both the short circuit current of solar cells in space and the degradation of solar cell efficiency in going from terrestrial conditions to space is presented. The results of this method are compared with telemetry measurements from a spacecraft in flight. The consistency of the data from the two different sources is demonstrated.

PERMUTED SUBJECT INDEX

Key words in the title of each of the articles referenced in this work have been rotated to the beginning of the title and alphabetized.

Thus, if one should search for the word "solar", it would appear alphabetically at the beginning of the line for all titles in which it actually occurs.

The number at the right corresponds to the bibliography citation number.

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13. ABSTRACT

This annotated bibliography contains 700 citations from open literature on power supplies. It is oriented toward batteries, fuel cells, thermionics, thermoelectrics, nuclear energy sources, and other new concepts of direct energy conversion which may be adaptable to space vehicles.

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